Dec, 2024
GRINS DISCUSSION PAPER SERIES DP N° 83/2026 ISSN 3035-5567

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DP N° 83/2026

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KEYWORDS

#Remote learning #Covid-19 #socio-economic disparities

JEL CODE

I21, I24, O33

ACKNOWLEDGEMENTS

Contacts: Adriana Di Liberto, diliberto@unica.it; Andrea Caria, andrea.caria91@unica.it. Sara Pau passed away during the writing of this manuscript and we acknowledge her invaluable contribution. This study is dedicated to her memory. Corresponding author: Adriana Di Liberto, University of Cagliari, Department of Economics and Business, Via S. Ignazio 17, 09123 Cagliari, Italy. We thank Fondazione Agnelli, especially Gianfranco De Simone and Martino Bernardi, for the contribution to the study, and the seminar participants at the ERSA conference 2023 (Alicante). The authors gratefully acknowledge funding from the Fondazione Giovanni Agnelli, the EU Horizon Program, project number Project 101061104 ESSPIN "ECONOMIC, SOCIAL AND SPATIAL INEQUALITIES IN EUROPE IN THE ERA OF GLOBAL MEGA-TRENDS," and the EU - NextGenerationEU, in the framework of the GRINS -Growing Resilient, Inclusive and Sustainable project (CUP F53C22000760007). The views and opinions expressed are solely those of the authors and do not necessarily reflect those of the European Union, nor can the European Union be held responsible for them.

CITE THIS WORK

Author(s): Andrea Caria, Adriana Di Liberto, Sara Pau. Title: Remote learning during the Covid-19 pandemic: evidence from a three-level survey of Italian schools. Publication Date: 2024.

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between teachers' perceptions of their digital skills and the actual use of ICT in class during RL activities. Our results identify a positive and robust relationship between the use of innovative teaching methodologies in class, the adoption of appropriate organizational innovations at the school level, and specific teachers' training with the student's perceptions of learning and other outcomes related to student success.

Remote learning during the Covid-19 pandemic: evidence from a three-level survey of Italian schools*

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December 12, 2024

Abstract

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Keywords and phrases: Remote learning; Covid-19; socio-economic disparities.
J.E.L. Classification: I21, I24, O33.

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1 Introduction

During the COVID-19 pandemic, many countries have opted to suspend in-person schooling to minimize contact and mitigate the spread of the virus. In April 2020, during the pandemic's peak, over 1.6 billion K-12 learners in more than 190 countries could not attend in-person schooling. The educational community put effort into continuing the learning activities remotely, and remote learning (RL hereafter) became a nationwide rage in most countries (Schleicher, 2020; Muñoz-Najar et al., 2021). As of October 2021, 32 percent of countries worldwide still had either fully closed schools or partially closed them.

After China, where the outbreak began, among the first countries to adopt school closure measures in response to the pandemic was Italy, which was also the first European country to be severely affected by the pandemic.[1] During the first wave of infections, from March 2020 to the end of the school year, in-person teaching was interrupted in schools of all levels across the country. The second wave of the pandemic, which began in European countries at the start of the 2020 fall, has seen Italian schools closed more than most industrialized/EU countries. While there is an increasing consensus that the impact of COVID-19 has produced learning loss and heterogeneous effects among different types of students and areas, there is less evidence of the mechanisms that may have influenced these results.[2]

The present study investigates the role of Italian teachers and school principals in promoting the introduction of organizational and teaching innovations during the pandemic. We focus on the *second* lockdown period, from September 2020 to June 2021. Unlike the first, concerning school organization, the second lockdown was characterized by a completely different context. RL was considered a likely possibility, and before the start of the new school year 2020-21, the Italian Ministry of Education produced the guidelines for the so-called *Didattica Digitale Integrata* or Integrated Digital Teaching (IDT henceforth), stating general rules about distance and digital learning in case of its adoption in schools.[3] However, these rules were not binding and left principals and teachers significant autonomy in deciding how to organize their activities using RL.

In this study, we exploit the resulting heterogeneity across Italian schools to

[1] Italy was one of the first countries in the world to implement school closures nationwide from March 4, 2020, as part of measures to contain the spread of COVID-19. It was also one of the countries that maintained the measure longer, especially for upper secondary schools (Camera dei deputati, 2022).

[2] See Section 2 for a survey on the impact of ICT in class and RL during COVID-19 on students' outcomes.

[3] *Decreto Ministeriale n. 89, August 7 2020, "Adozione delle Linee Guida sulla Didattica digitale integrata" e Linee guida.* Note that freedom of teaching is a principle established by the Constitution of the Italian Republic, even if there are National Guidelines for the Curriculum that set out basic methodological approaches.

investigate the role of different organizational decisions and teaching practices on several outcomes. To this aim, we collect data from a unique three-level survey, obtaining a large sample of upper secondary students, teachers, and principals who attended those schools during the second lockdown. Our rich dataset provides detailed information on how each school reorganized RL activities, the teaching methodologies implemented/carried out, on the perceptions about the effectiveness of teaching on both cognitive competencies and other outcomes, and the quality of interpersonal relationships during RL. As far as we know, this is the first study that collects a large dataset in each school for the three main school stakeholders (overall 14,447 observations across school principals, teachers, and students) on how they perceived the experience of schooling during the pandemic. We focus on upper secondary schools since, unlike primary and lower secondary schools, in Italy, they undergo a more prolonged period of school closure and use of RL.[4]

First, we observe that despite the Government's recommendations to modify their organization and teaching methods during online learning, Italian schools struggled to implement even small changes during RL activities. Most schools replicated traditional in-person teaching methods and schedules. Survey responses indicate that online activities largely mirrored the in-person timetable, with few modifications, even after the first emergency period. There was significant heterogeneity in the quantity (and, quite likely, also in the quality) of digital skills training provided to teachers. We also find that, despite this, many teachers believed their digital skills were adequate for online teaching during the COVID-19 pandemic.

Second, using measures of perceived learning loss, our analysis confirms findings from numerous studies: most students reported learning less during online activities than they would have during in-person activities. More importantly, RL had uneven effects and increased inequalities, as more vulnerable students perceived more significant learning losses than advantaged students.

Our regression analysis supports these results. Further, it suggests that using innovative teaching methodologies and adopting appropriate organizational models during RL activities positively correlate with students' learning perceptions, with evidence robust across different model specifications. Specifically, the student's perception of the learning variable is always positively correlated with the use of innovative online teaching methods in class. At the same time, a negative relationship was found with schools that did not change their organizational practices during RL. Additionally, using effective online teaching methodologies is positively associated with a better overall RL experience, a desire to continue using online activities post-pandemic, and enhanced perceptions of interaction quality with teachers and

[4]Moreover, the length of in-person schooling across the different areas during the school year 2020-21 was not alike. During the second lockdown in Italy the use of digital or remote learning varied across levels of schooling, regions and even municipalities based on specific area laws (Bovini and De Philippis, 2021; Conteduca and Borin, 2022).

peers. Finally, the intensity of innovative teaching methods implemented in class is significantly correlated with the extent of teachers' training received by teachers during the pandemic.

In sum, this study contributes to the relatively limited literature on how schools have reorganized in response to the lockdown, exploring key mechanisms that may have influenced remote learning (RL) effectiveness and factors that may have exacerbated learning inequalities.[5] Our research also adds to two distinct strands of the educational literature. First, while there is growing consensus and quantitative evidence on the importance of teacher quality in shaping student outcomes (Hanushek, 2011; Chetty et al., 2011; Rivkin et al., 2005; Hanushek and Rivkin, 2012), less is known about how to improve teacher effectiveness. Our teacher survey adds to the literature by highlighting the critical role of teachers' digital skills and the integration of Information and Communication Technology (ICT) in learning activities. Second, an expanding body of research considers school organization and management as pivotal in explaining variations in student learning, with evidence from Italy as well (Bloom et al., 2015; Di Liberto et al., 2015; Agasisti et al., 2020). This literature emphasizes the indirect yet significant influence of school principals on student outcomes by creating favorable teaching and learning conditions (Di Liberto, 2017; Robinson et al., 2008; Grissom and Loeb, 2011). Our principals' survey contributes by specifically examining the role of school organizations during the pandemic. Finally, this analysis offers valuable insights on how to better equip schools and teachers facing new technological changes that, like AI, are rapidly and significantly reshaping society, including education and schooling.

The remainder of the paper proceeds as follows. Section 2 briefly describes the literature on using ICT in class and the effect of online activities during the pandemic on student learning losses. Section 3 provides information on our survey and the data collection process, with the descriptives at the school principal (3.1), teachers (3.2), and students (3.3) levels. More descriptive evidence on inequality patterns is in Section 4, while Section 5 describes the results obtained by the regression analysis. A final discussion of the findings and possible implications for policymakers is in Section 6.

2 ICT, online learning and pandemic consequences: a review of the literature

This section offers a brief overview of the main recent findings on the role of Information and Communication Technology (ICT) in learning outcomes and the impact of the COVID-19 pandemic and subsequent school closures on students' educational

[5] One exception for Italy is the study by (Bertoletti et al., 2023), explicitly focusing on teachers' experiences in primary and middle schools during the initial emergency lockdown.

outcomes. We separate the two streams of the literature since the effect of digital technology in schools may differ during school closures compared to standard school years (Carlana and La Ferrara, 2024).

Before the pandemic, various studies explored whether and how ICT technologies could transform teaching and students' learning. Overall, the evidence on the impact of ICT on learning outcomes is mixed, and both pre and post-pandemic studies on Internet-enabled classroom technology identify both positive and negative effects on student performance. On the positive side, ICT may make education more effective, engaging, and accessible. Possible positive impacts include enhanced group activities, immediate feedback, faster note-taking, and easy storage of notes (Carter et al., 2017). Comi et al. (2017) and Rovai (2001) find that increased connectivity outside the classroom fosters communication and collaboration among peers, schools, and families and supports the co-production of knowledge among teachers. Some evidence suggests that learning communities enhance a sense of connectedness, shared knowledge, and common goals, which can reduce dropout rates (DiRamio and Wolverton, 2006). Additionally, "enhanced" textbooks have been found to offer capabilities such as embedded videos and hyperlinks, benefiting both students and teachers with specific educational software for tracking progress (Anderson et al., 2001). More recently, Carlana and La Ferrara (2024) identified a positive effect of a Tutoring Online Program (TOP) both during (2020) and after (2022) the pandemic on the math performance of underprivileged middle school students, with additional effects on aspirations, socio-emotional skills, and psychological well-being.[6]

However, other studies suggest that the use of ICT in class can negatively impact student learning. Carter et al. (2017) find lower exam scores in computer-using groups. Bakia et al. (2013) highlight potential inequalities, with advantages accruing to students with stronger academic backgrounds, self-discipline, and access to technology at home. Additionally, computer use can be a distraction, leading to web-surfing and reduced academic performance, as evidenced by Barak et al. (2006) and research on multitasking with laptops (Fried, 2008; Kraushaar and Novak, 2010; Grace-Martin and Gay, 2001). Moreover, the lack of interaction between learners and instructors, and among learners themselves, can lead to feelings of isolation (Hughes et al., 2007; Xiaojing et al., 2007; McInnerney and Roberts, 2004; Pigliapoco and Bogliolo, 2008).

In contrast to the mixed findings on ICT, there is a broad consensus in the second stream of literature on the pandemic's substantial negative and uneven impact on students' educational outcomes across different countries and school levels.[7] Most studies estimate the effect of the pandemic on student achievement by comparing cohorts of students affected by school closures with those unaffected, controlling

[6]These effects are identified only during the school closure periods.

[7]For more on this, see the surveys by Hammerstein et al. (2021); Storey and Zhang (2021); Di Pietro (2023).

for various characteristics such as prior achievement, family background, gender, migrant status, and geographic area of residence. Many studies highlight the unequal impact of COVID-19 on students. Engzell et al. (2021) and Haelermans et al. (2022), where an 8-week lockdown resulted in significant learning losses in primary schools in the Netherlands, ranging from 0.08 to 0.21 standard deviations in math, spelling, and reading, with losses up to 60% more prominent among students from less-educated households. Similar results are found in Belgium by Maldonado and De Witte (2022) comparing standardized test scores of the students in the last year of primary school in 2020 who were affected by school closures with previous cohorts. They find a decrease in mathematics and language scores by 0.17 and 0.19 standard deviations, respectively. In Switzerland, Tomasik et al. (2021) report that secondary school pupils were mainly unaffected, whereas primary school students experienced a learning slowdown of approximately 0.2 SD during an 8-week closure. In Norway, Skar et al. (2022) observed a 0.24 SD decrease in reading performance among first-grade students during the 2019/20 school year compared to their peers before the pandemic. Further, school closures seem to have exacerbated already existing inequalities, with heterogeneous effects on achievement based on student and family characteristics. Pupils from low socio-economic backgrounds, those with lower prior achievement, minorities, students with poorer home learning environments, and those experiencing more extended school closures were most affected (Asakawa et al., 2021; Contini et al., 2021, 2023; Grewenig et al., 2021; Halloran et al., 2021; Strunk et al., 2023; Di Pietro et al., 2020; Engzell et al., 2021).

Evidence on Italian students is no exception. Contini et al. (2021) estimated the effects on primary school children, finding a negative impact on mathematics achievement (-0.19 SD). Learning losses were more significant among children of low-educated parents, particularly for the best-performing students (up to -0.51 SD) and for girls (-0.29 SD). Bazoli et al. (2022) found significant learning losses in reading and mathematics, especially severe in mathematics, among Italian students in grades 5, 8, and 13. Borgonovi and Ferrara (2023) reported an 85% reduction in expected yearly learning gain in mathematics and a 40% reduction in reading for lower secondary students, with smaller but still significant losses for primary students. Contini et al. (2023), found that the pandemic harmed upper secondary school students' performance in mathematics and reading (approximately 0.4 SD in both subjects). Finally, unlike the previous studies, Alderighi et al. (2023) use a different outcome variable, a measure of hidden drop-outs: these are students who formally completed secondary school but did not acquire a level of competencies and skills that can be considered sufficient in standardized test results. Alderighi et al. (2023) used standardized test results to measure hidden drop-outs, finding an 8.6% increase in students not reaching minimum competency levels, particularly among those with lower prior achievement, from poorer families, and emotionally disrupted during assessments.

3 The three-level survey

To construct the dataset, we conducted a three-level survey where different questionnaires were administered to upper secondary students (namely, 11th and 13th graders), their teachers, and school principals of each institution.[8]

Our three final samples include 10,730 students (6,596 11th and 4,134 13th graders), 3,612 teachers, and 105 school principals.[9] As far as we know, this is a unique feature of our data.[10] The data collection process started in March and ended in June 2021. More details about the data collection are described in Appendix A.1.

Tables A1 and A2 first compare some key characteristics of our sample with those of the population of Italian upper secondary schools. The sampling was conducted by randomly selecting the 5% of schools within each Italian macroarea (NUTS 1), stratified by school types to take into account the school tracks that in Italy start at grade nine and the geographical differences observed within the country in the quality and quantity of educational outcomes.[11] The Italian system offers students three main options between general or academic (*Licei*), technical (*Istituti Tecnici*) and vocational (*Istituti Professionali*) studies, and students choose to enrol in one of these three educational pathways which all provide access to higher education.[12] Despite that, a large empirical evidence shows that this initial sorting would also translate into a social tracking: students in general/academic track attain higher educational achievement, and come from a higher socio-economic status than those in vocational tracks (Brunello and Checchi, 2007).

In our analysis, we only include schools where at least 15 students and 8 teachers submitted the questionnaire. Considering the exceptional nature of the pandemic and the resulting organizational disruptions and psychological challenges faced by the schools, we expected that some of them were not willing to participate in the project or complete the questionnaires, especially those experiencing greater difficulties. To compare our sample with the population characteristics, we merge the survey data with the administrative dataset ("*La scuola in chiaro*") on student performance and school characteristics provided by the Italian Ministry of Education

[8]The surveys have been designed with the contribution of the Fondazione Giovanni Agnelli. See also https://www.fondazioneagnelli.it/2021/07/09/la-dad-alle-scuole-superiori-nellanno-scolastico-2020-21-una-fotografia/.

[9]The data also identify when a school has different locations, or *plessi* and identify 163 plexes. In some analyses, we also exploit the presence of these sub-groups.

[10]There are exceptions, but they usually include a limited number of interviews. See, for example, (Carretero Gómez et al., 2021) that interviewed 29 stakeholders (5 students, 5 parents, 13 teachers, and 6 school school leaders) in Italy.

[11]On geography and educational outcomes in Italy see among the others Di Liberto (2008).

[12]Unlike other countries, Italian upper secondary school tracking is not determined by a formal assignment process to academic or vocational courses depending on students' past performance or by any alternative selection processes.

(MIUR).

Previous studies show that schools located in the northern and more developed Italian regions and Lyceums have better student results and also implement better managerial practices compared to, respectively, other regions and school types (Di Liberto et al., 2015, 2023). Data in Table A1 reveal some oversampling of schools located in the northern area and a larger share of Lyceums than the population, confirming our expectations that *better* schools were likely to be keener to answer the survey.[13] Further, Table A2 shows the sampling balance in terms of grade retention rates, dropouts, and the share of students who transfer to and from other schools. The data on dropouts indicates the percentage of students who have discontinued school attendance during the school year. Numbers confirm the presence of an oversampling of "better" schools: our sample has fewer dropouts and lower retention rates than the population. When interpreting our evidence, we will take into account this selection issue.

The following three sections investigate the different perspectives about the remote schooling experience during the second lockdown provided by, respectively, school principals (SPs henceforth), teachers, and students.[14]

3.1 The school principals perspective

Most information about the decision-making processes adopted by the Italian schools during the second school lockdown is investigated in the SPs section of our Survey. We have collected 105 interviews with questions focusing on the organizational structure of schools during RL synchronous activities and their implementation of the IDT plan between September 2020 and May 2021.

The COVID-19 pandemic has dramatically impacted the principals' overall organizational burden and their ability to organize teaching-learning activities. During the *first* Covid-19 wave (March-June 2020), the teaching and organizational approach implemented in schools has been defined as Emergency Remote Teaching (ERT) as it caught the authorities and schools by surprise all over the world, including Italy (Bertoletti et al., 2023). Due to the sudden school closure that occurred in the spring of 2020, the Italian Ministry of Education did not offer detailed guidelines but only very few emergency rules, including a) the non-mandatory nature of adopting RL, b) the impossibility for teachers to conduct written assessments, and c) it suspended grade retention for the 2019-20 school year acknowledging that schools were unable to cope with the pandemic situation.[15] Besides that, each school organized itself in almost full autonomy.[16]

[13]For more on this see Section 3.1.

[14]The three surveys are available upon request.

[15]On this, see also Contini et al. (2023).

[16]In Italy, school principal as a managerial figure has been established by law *D.lgs March 6, 1998, No. 59*, and specified by *D.lgs March 30, 2001, No. 165*. Thus, since 2000, Italian schools

Unlike the first (March-June 2020), during the second lockdown, the Italian Ministry of Education provided specific guidelines for the so-called Integrated Digital Teaching or IDT. In sum, Italian SPs received new directives and health procedures meant to promote the effective regulation of the school during both schools' activities in presence and possible new lockdowns with RL activities. Each school had to develop a specific Plan for IDT (*Piano per la Didattica Digitale Integrata*), and all decisions about the organizational changes were coordinated with the teaching staff. Following the guidelines, during the RL synchronous activities, upper secondary schools were allowed a) to modify the schedule of in-presence activities while ensuring sufficient weekly time for all subjects, b) to reduce the length of each lesson, c) to consolidate the subjects taught and d) to implement other forms of organizational flexibility. With few exceptions, during lockdowns, these guidelines also allowed for flexible modifications to the weekly timetable and overall school organization with the aim of making remote learning more effective.[17] Upper secondary schools were only required to provide at least twenty weekly hours of synchronous teaching with the entire class group, with the option to add small-group activities and asynchronous learning activities.

Overall, the government guidelines made a clear suggestion for schools to change their organization during RL activities and use ICT-related practices and teaching methodologies. Figure 1 describes the schools' decisions taken in terms of timetable and duration of the lesson changes allowed during RL. Panel a) indicates that most schools (65%) decided to replicate online their pre-pandemic school timetable. Only 26% opted for reducing the number of hours spent on synchronous compared to the original timetable implementing a proportional reduction in the number of hours for each subject taught.[18] Finally, a mere 8% have decided to make additional modifications, specifically by prioritizing core subjects like Italian, math, or foreign language over others. Plus, this choice has predominantly been made by vocational schools that experienced more difficulties in adapting specific activities and subjects (such as labs and students' work-related training) to an online format. Lab activities have been reduced due to the lack of collaboration from local authorities (20%), student absenteeism (12%), opposition from families (18%), or explicit resistance of teachers (18%).[19]

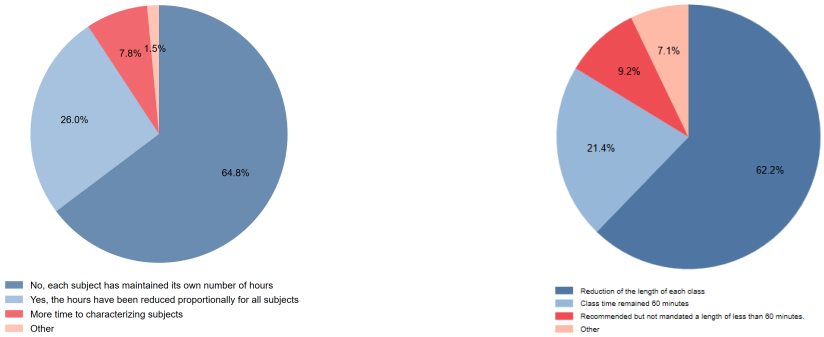
have enjoyed greater organizational autonomy, and SPs have become school managers with full responsibility for the school budget, coordination, and human resource management.

[17]The decree of the Minister of Education on June 26, 2020, No. 39, while the guidelines have been published in August 2020.

[18]The survey question was: "Does your school revisited the hourly distribution and relative weight of the different subjects in the total weekly hours of synchronous instructional activities?", and 65% answered, "No, each subject has maintained its own number of hours."

[19]This switch has also been observed for the students' work-related training projects (*Percorsi per le Competenze Trasversali e per l'Orientamento*, PCTO). At the time of the survey, SPs expected to be able to complete around 70% of them at the end of the school year.

Figure 1



(a) Number of hours of synchronous teaching during RL

(b) Timing reduction

Notes: *Panel a) depicts the weekly number of hours (by subject) of synchronous teaching during RL, while Panel b) shows the duration of the unit lesson and whether a time reduction was implemented. Schools where the lesson's length was already less than 60 minutes are in a residual (other) category.*

As suggested by the national guidelines, schools could also reduce the duration of the individual synchronous lessons, and Figure 1 panel b, shows that 62% opted for this choice, but more than 30% decided or recommended a duration of online classes of 60 minutes.

We also ask the SPs if teachers have changed their educational methodologies during RL. The Italian government guidelines on IDT also promoted the use of teaching methods that differ from traditional in-person teaching. In detail, these guidelines aimed to "avoid teaching contents and methodologies being the simple transpositions of those implemented in person, and ensure a general level of inclusiveness, according to the educational literature on the effectiveness of Internet-enabled classroom and ICT teaching practices".[20] As seen in Section 2, the literature on ICT-related teaching methods suggests for RL the use of methodologies that focus more on student engagement, interdisciplinarity, and class discussions. Examples include brief teaching, cooperative learning, flipped classrooms, and debates, which are all based on students' active participation and construction of knowledge. Despite that, the large majority of SPs, 62%, answered that frontal lessons have been the most common practice in their school, and also suggested that the absence of innovation has been determined by a lack of teachers' expertise. In details, the SPs perception was that, during RL activities, a significant percentage of their teachers (at least 1 out of 4) needed support for the adoption of ICT methodologies for students' assessment (72%), for applying ICT teaching methodologies in class (69%)

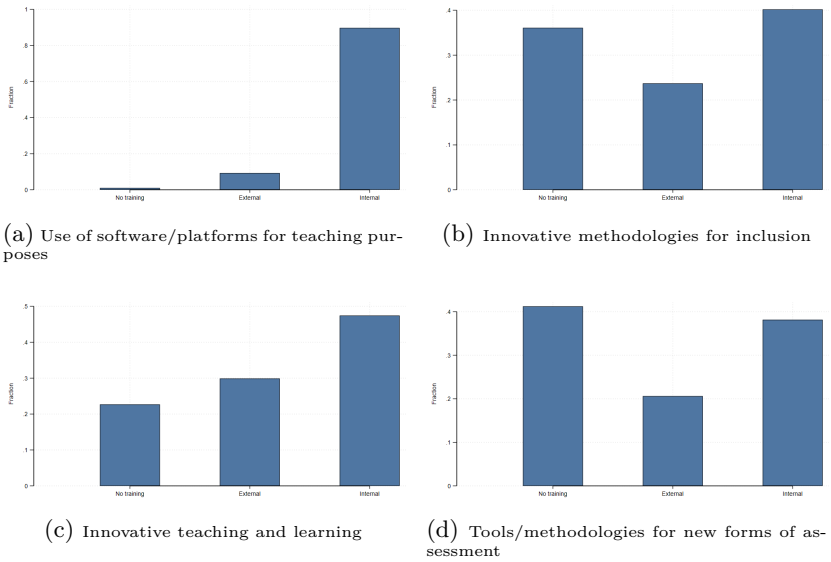
[20] https://www.miur.gov.it/documents/20182/0/ALL.+A+_+Linee_Guida_DDI_.pdf/f0eeb0b4-bb7e-1d8e-4809-a359a8a7512f

for interdisciplinary teaching models, and 61% for innovative teaching, and also for the use of new software (40%).

Finally, Figure 2 describes if, given this perceived lack of abilities, schools have provided (as also suggested by the national guidelines) specific training to enable teachers to improve their digital literacy. In Italy, schools have autonomy in providing continuous training for in-service teachers. Decisions on training are made during collegial meetings led by the principal and involve all teachers (*Collegio dei docenti*). Legally, principals are required to promote and coordinate experimental and ongoing training activities within their schools, thus playing a significant role in supporting different training options. However, training funding is limited and, despite the schools' autonomy, determined by the central government. The amount of funding each school receives is based on the number of teachers, disadvantaging smaller schools which tend to receive less financial support than larger ones. Smaller schools, often located in rural or southern regions, are more likely to serve vulnerable students and may find it challenging to afford high-quality training. These schools can overcome such financial and resource limitations by collaborating with other schools. However, this requires considerable organizational effort and a cohesive strategy among school principals and each *Collegio dei docenti*. Overall, even before the COVID-19 pandemic, the interplay between these funding mechanisms and the autonomy granted to schools posed a risk of creating disparities in the quality of training available across different parts of the country.

Data indicate that during Covid-19 schools offered some training primarily on the use of new software rather than on ICT-related teaching and assessment methodologies. For the latter, between 20 to 40% of schools offered no training.

Figure 2. Teachers' training: the School Principals perspective



(a) Use of software/platforms for teaching purposes

(b) Innovative methodologies for inclusion

(c) Innovative teaching and learning

(d) Tools/methodologies for new forms of assessment

Notes: *the figure presents an analysis of teacher participation in digital literacy training programs offered by schools. It details the percentage of teachers who have completed specific training initiatives designed to enhance their digital skills. The figure further differentiates between training programs facilitated internally by the schools themselves and those delivered by external organizations.*

Moreover, Figure 2 tells us that, when schools provided some training, for the most part, it was produced with internal school resources, possibly with the help of the digital team, digital animator, or expert teachers. Again, the evidence offered by Figure 2 calls into question that both the quality and quantity of the training offered during the Covid-19 shock was homogeneous across schools and the appropriate one given the emergency situation faced by schools, teachers, and students. The likely absence of a consistent standard in the digital training of Italian teachers could have contributed to increased inequalities in student learning during the pandemic. Evidence also suggests that previous policies did not provide teachers with the necessary digital skills to cope with the RL activities.[21]

In sum, these descriptives suggest that, although significant organizational changes were not only allowed but encouraged by the Government, during the synchronous distance learning activities, Italian schools decided to make very few changes in the timetable compared to in-presence schooling. A large share of schools, 23%, did not make any change: their RL synchronous activities were the same as the pre-pandemic in-presence one, including the 60-minute lessons. This implies schools faced significant difficulties in shifting online activities from a traditional content transmission

[21] On this see also (Bussu et al., 2023).

moment to alternative and more appropriate approaches.[22] We will further discuss these issues in Section 3.2 below, which focuses on the teachers' perceptions.

3.2 The teachers perspective

Our teachers' survey focuses on the importance of teachers' digital skills and on the integration of Information and Communication Technology (ICT) into learning activities. Our main objective was to evaluate how teachers during the second wave of the pandemic managed mainly the new synchronous remote teaching tasks, their ICT training and competencies, and their perceptions of the effectiveness of the implemented online teaching strategies.

Our sample comprised 3,612 teachers: 33% taught math and science, 27% humanities, and 15% foreign languages, with the remainder teaching various other subjects.[23] Additionally, 46% taught in lyceums, 31% in technical institutes, and 23% in vocational schools. A significant portion of the sample also held additional responsibilities within their schools: 46% were class coordinators, 36% had no additional duties beyond teaching, and the remainder held various other positions.

Among these, we also find that 4.4% were digital animators or members of the innovation team. These figures were established in 2015 under the National Plan for Digital Education (Law 107), introduced by the Italian government to address the significant ICT gap between Italy and other industrialized countries in schools. This gap has been longstanding; data from 2011 showed that Italy lagged behind most OECD countries in ICT integration in education, with only 30% of Italian 8th-grade students regularly using ICT in science classes, compared to the OECD average of 48% Avvisati et al. (2013). A contributing factor to the digital skills deficit in the Italian education system may be the age of its teaching staff: older workers are generally less likely to participate in training or innovate compared to younger workers (OECD, 2023). According to OECD (2021), in 2019, 58% of primary school teachers, 53% of lower secondary, and 62% of upper secondary teachers in Italy were at least 50 years old, compared to OECD averages of 33%, 36%, and 40%, respectively. To address this gap, digital animators and Digital Innovation Teams were established in each school to provide specific training and active support for educational innovation, promoting a digital culture.

Our data indicates that the digital skills gap of Italian teachers persisted during the second lockdown. Figure 3 panel (a) illustrates the frequency with which teachers employed various teaching practices between September 2020 and the interview. The spider plot reveals that traditional transmissive methods such as video

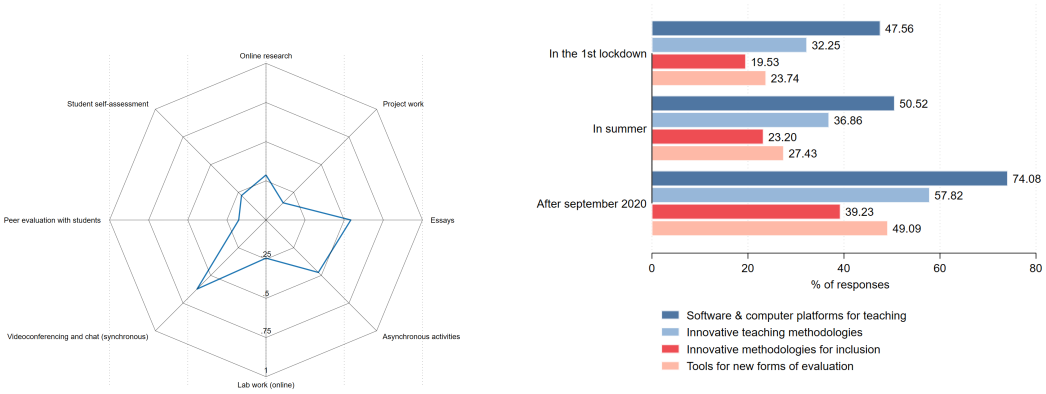
[22] This percentage is obtained by cross-referencing the answers of two different principals' survey questions on the timetable and class duration.

[23] Of these, 52% teach both third and fifth graders, while 28% and 20% teach exclusively to third and fifth graders.

lectures, instructor-led discussions, and home assignments were the most popular methodologies. In contrast, options like online research, online lab activities, student self-assessment, peer evaluation, and project work were rarely utilized. We did not observe significant variation between school types, although minor differences emerged across subjects taught: teachers of foreign languages, possibly accustomed to less traditional teaching approaches even before the pandemic, reported more frequent use of innovative teaching methods. Overall, this analysis confirms the principals' perceptions and that the adoption of innovative teaching approaches in class was more an exception rather than a rule.

Secondly, we surveyed participants about the extent of their training during the entire pandemic period to address skill gaps needed for their new online activities. Figure 3 panel (b) shows that a substantial portion of training occurred during the first emergency teaching period (from March to June 2020). Additionally, considering the full period from March 2020 to the moment of the interview), nearly 80% received training on new software skills, but only about 50% reported receiving training on innovative teaching and assessment methodologies.

Figure 3. Teachers' activities and training during the lockdown



(a) Teaching methodologies during RL

(b) Cumulative % of teachers that received training

Notes: *The spider plot in Panel (a) identifies the frequency with with teacher introduced different methodologies during RL. Higher frequencies are depicted farther from the center, approaching the outer edge of the "web," while values closer to zero lie nearer the center. This spider plot uses multiple axes radiating from a central point and enables it to easily identify frequency at 25%, 50%, 75%, and 100%. Panel (b) illustrates the cumulative percentage of teachers who have completed training in four different specific areas during three different periods: March-June 2020 (the first lockdown), July and August 2020, and September til the interview.*

Third, despite the teachers' self-reported infrequent use of innovative teaching methodologies and potential inadequacies in training, their confidence in their digital

abilities and capability to effectively conduct online teaching was high: 85% of surveyed teachers indicated they possessed sufficient or entirely adequate skills for remote teaching and learning activities during the pandemic.[24]

Altogether, these findings present a somewhat puzzling picture, as they seem to contradict each other. The most straightforward explanation for the inconsistency between infrequent use of innovative activities during remote learning, reported weak training on ICT teaching methodologies, but perceived adequate digital abilities is that teachers overestimate their digital skills, a well-documented phenomenon in the literature on self-perception bias. A complementary explanation is that Italian teachers may have viewed distance teaching as simply an online adaptation of traditional transmissive teaching. This hypothesis would reinforce, again, the idea that both the quantity and quality of the digital skills training offered were inadequate to successfully implement more effective teaching methodologies for remote learning. It is also plausible that the low-quality digital skills training offered was insufficient to be effective but, at the same time, has contributed to teachers' overestimation of their digital competencies. In this case, we would have a situation where it would have been better not to provide any training rather than offer a low-quality one. However, in the absence of additional data and information, this is merely a suggestion that requires further investigation.

Finally, this evidence aligns with teachers' views on how school organization should have changed during periods of school closure. Consistent with expectations, decisions made by school faculty boards (Consiglio d'Istituto), which include teachers, revealed strong consensus for minimal organizational changes and maintaining a synchronous online timetable similar to pre-pandemic schedules. The majority (85%) of teachers considered transposing the pre-pandemic timetable online appropriate, with only 6.4% believing the synchronous workload was excessive, mostly among teachers whose activities, such as laboratory work, were challenging to translate online.

Before starting the next section, it is worth noting that, just like the schools, this evidence of a limited willingness to innovate comes from a large sample of teachers who agreed to respond to our questionnaire and likely represents a positive selection of more motivated and engaged Italian teachers.

3.3 The students perspective

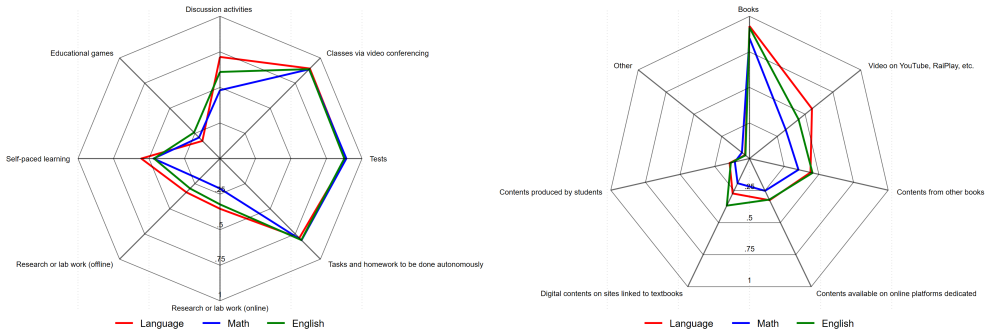
We now turn our attention to the students' perceptions during the critical period of the Covid-19 pandemic. First, our students confirmed that in almost all schools during remote learning (RL), both the timetable for synchronous activities and the

[24] They answered the following question: Coping with the need to carry out Distance Teaching and Learning activities, in your opinion, your technological and teaching skills proved to be adequate to meet the new requirements?

teaching methodologies used were almost entirely an online replication of in-person school hours. Specifically, 91% of students reported spending between 5 and 6 hours a day on video for synchronous activities during online learning, with a distribution across subjects that matched their original timetables.

Second, we asked our students about the teaching methodologies implemented in class during RL.[25] Figure 4 panel (a) shows that nine out of ten students reported that their teachers primarily used three activities during RL: video lessons, assessments, and homework. Conversely, alternative activities such as independent or group research activities (both online and offline), educational games, apps, and interactive exercises were rarely used.

Figure 4. Teaching activities and additional learning materials



(a) Teaching activities

(b) Additional learning materials

Notes: *we show the spider plot depicting the frequency of teacher methodologies during RL from the student perspective. The greater the distance from the center on a particular axis, the higher the average probability that teachers employ that specific practice.Panel a) depicts the teaching activities while Panel b)illustrates the additional learning material*

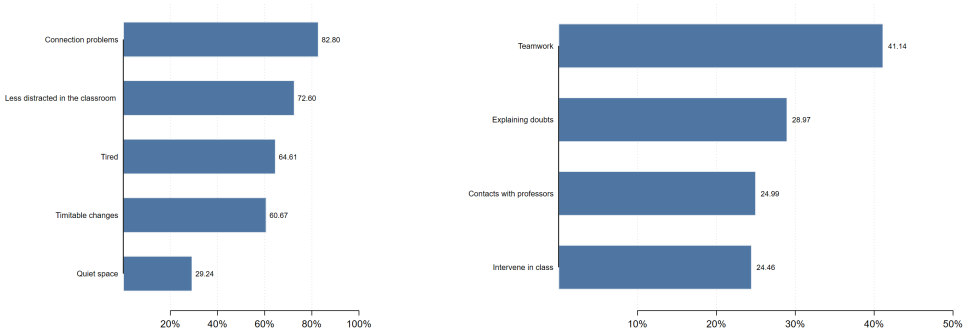
Figure 4 panel (b) describes how often teachers used different types of additional learning materials during RL. Besides traditional textbooks (used by 85% to 93% of students depending on the subject), only 1 out of 10 students were asked to produce their own learning materials, while other sources of learning material were rarely proposed.

Figure 5 shows that compared to face-to-face teaching, most students reported a greater sense of fatigue (65%) and difficulty in maintaining attention (73%) after a day of RL. Only 1 out of 4 students found it easier to interact with teachers or ask for

[25]The students' responses concerning classroom activities pertain to one of four subjects covered in class: Italian, Mathematics, English, and another significant subject relevant to their particular course of study. During the survey, students were randomly assigned one of these four subjects. Students' evidence does not identify significant differences across subjects on the use of different activities in class.

more details during online lessons. The absence of traditional classroom socialization was another negative aspect of online learning noted by students, along with continuous revisions to school organization (online, in-person, timetable changes, etc.) due to fluctuating pandemic waves, which 61% of students perceived as complications.

Figure 5. Remote Learning: perceived quality and students' attitudes



(a) Issues

(b) Students' interaction

Notes: *This figure presents the percentage of students who agree and strongly agree with survey questions concerning the challenges faced during remote learning (Panel A). Additionally, it examines student perceptions of their own attitudes and the quality of the remote learning experience (Panel B).*

In sum, the students' point of view confirms that during the second lockdown, their schools replicated online the traditional teaching methods, i.e., RL activities did not seem to stimulate the introduction of innovative or alternative learning materials and teaching methodologies. This can be one factor that explain why a large proportion of our students perceived their online learning experience as a negative one. They struggled more not only to interact with the teachers but also to follow the lessons in RL. These perceptions were also fully confirmed by their teachers, who described how RL caused significant deterioration in various dimensions of the relationship among school actors (students, teachers, and families).[26]

In this study, we exploit the extensive information provided by the answers of approximately 11,000 students to construct three important indicators: their perceived innovativeness of the educational methods used in class, their socioeconomic status, and their motivation and perception of self-efficacy in learning during RL. All these indicators were constructed using factor analysis.[27]

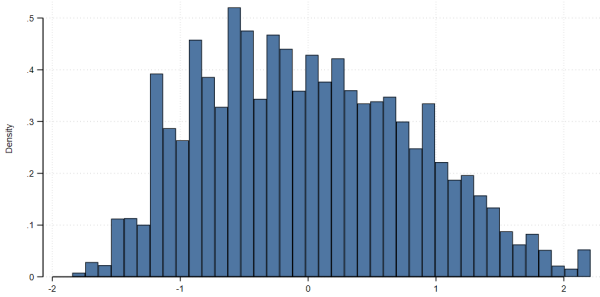
We first used our students' answers on innovative activities implemented in class

[26]For more details, see the Appendix, Figure A1.

[27]Factor analysis is a statistical approach used to reduce data complexity. It seeks to identify latent variables (factors) that affect different observed variables and explain their relationships by creating linear combinations of variables that capture the most important information and that can be meaningfully interpreted.

to calculate a synthetic index measuring the degree of innovation in online teaching utilizing students' responses on "how often they used innovative teaching practices in class" as described in Figure 4. Figure 6 depicts the distribution of this new index with low/high values indicating low/high levels of innovation of teaching methodologies adopted in class. The Figure shows a slightly right-skewed distribution and a significant heterogeneity across students.

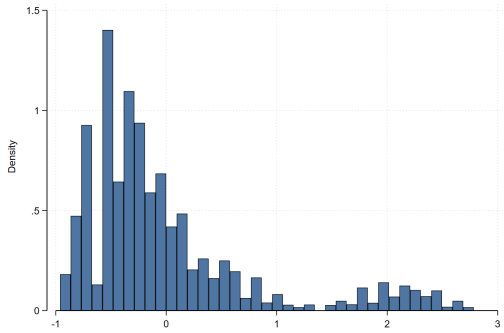
Figure 6. The distribution of the innovative teaching index



Notes: *The innovation index is constructed with factor analysis using the answers on innovative teaching methodologies adopted in class.*

Further, our survey includes a specific set of questions that allows us to calculate our students' socio-economic status (SES) by using different answers to questions that identify factors impacting students' ability to actively and effectively participate in RL classes. These factors mainly include student-reported possessions at home, such as the lack of a quiet space, sharing a device for RL, connection problems, and satisfaction with device use. We then obtained a SES or *deprivation* index that enables us to identify students who, during the second lockdown, were more vulnerable in terms of their families' capacity to provide the necessary tools for effectively following RL.

Figure 7. The distribution of the deprivation index



Notes: *The deprivation index is constructed with factor analysis using the answers on student-reported possessions at home (such as the lack of a quiet space, sharing a device for RL, connection problems) and satisfaction with device use.*

Figure 7 shows the distribution of this index. Low values indicate low levels of deprivation and a corresponding high-SES status, while high values indicate high levels of deprivation and low SES. The figure shows a right-skewed distribution, possibly due to the selection of better schools discussed above, as well as numerous interventions carried out between the first and second lockdowns by schools and the Italian government aimed at bridging the resource gaps between less and more vulnerable families, such as providing tablets or computers (Contini et al., 2023).

The final index uses answers to the nine questions reported in Table 1, aimed at capturing a) the quality of the student's experience, engagement and sense of belonging at school, and b) noncognitive skills identified as important predictors of students' educational outcomes, such as general attitudes towards school and learning outcomes as well as attitudes towards learning activities (Buchholz et al., 2022; Zhou, 2016). We used the answers to all these questions to calculate a synthetic index of students' motivation and perception of self-efficacy at school through factor analysis. For brevity, we refer to it as the self-efficacy index.[28]

In Table 1 we also investigate the presence of heterogeneity in attitudes/motivations across different types of students. We split the students' sample using the median of our deprivation/SES index into those scoring below the median (low deprivation/high SES) and above (high deprivation/low SES). The final row of Table 1 includes the average value of the self-efficacy index divided for the two subgroups. As expected, the results suggest that the self-efficacy index is significantly higher for high-SES students.

[28]These questions have been used in different OCSE-PISA surveys (Buchholz et al., 2022). Questions 3 and 4 are identified as indices for work mastery and Questions 5 and 7 for perseverance. Finally, Questions 8 and 9 capture how students value schooling outcomes.

Table 1. Students perseverance and motivation in learning by socio-economic deprivation

	Low deprivation	High deprivation	Difference
Q1 - I enjoy receiving good grades	3.723	3.649	0.074***
Q2 - Trying hard at school is important	3.429	3.414	0.015
Q3 - I continue working on tasks until everything is perfect	3.435	3.356	0.079***
Q4 - Part of the enjoyment I get from doing things is when I improve on my past performance	3.375	3.353	0.022
Q5 - If I am not good at something, I keep trying until I master it	3.154	3.098	0.057***
Q6 - My goal is to avoid doing worse than my peers	2.398	2.471	-0.073***
Q7 - I enjoy exploring topics in as much depth as possible	2.642	2.636	0.006
Q8 - Trying hard at school will help me get a good job	3.082	3.055	0.027
Q9 - Trying hard at school will help me get into a good college	3.265	3.205	0.060***
Index - Perception of self-efficacy	2.546	2.454	0.092***

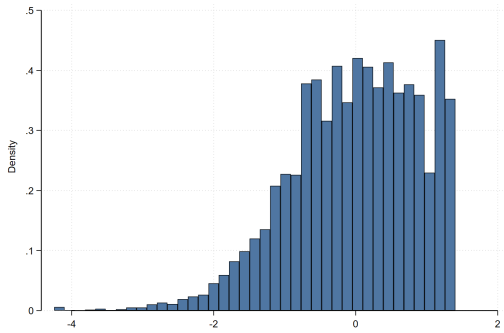
Notes: *Students had to indicate how much they agreed with each statement using the following scale: 1-Strongly disagree, 2-Disagree, 3-Agree, 4-Strongly Agree. Students are categorized as experiencing low deprivation if their deprivation index score falls below the median of the distribution. Conversely, students with scores exceeding the median are classified as experiencing high deprivation. The t-test of equal means reported with significance levels identified by * 10%, ** 5%, *** 1%.*

As expected, the data suggest that more vulnerable students are less perseverant, have less motivation to study, and place less value on the potential returns of academic outcomes. These differences between low and high SES students are statistically significant in most cases.

Moreover, Figure 8 depicts the distribution of this new self-efficacy index. The figure shows a left-skewed distribution, where low values indicate low levels of perceived self-efficacy, and vice versa.

Overall, all the indexes described above seem to confirm the school selection, but they also show the presence of significant heterogeneity across our students' sample. We will exploit them in our following regression analysis.

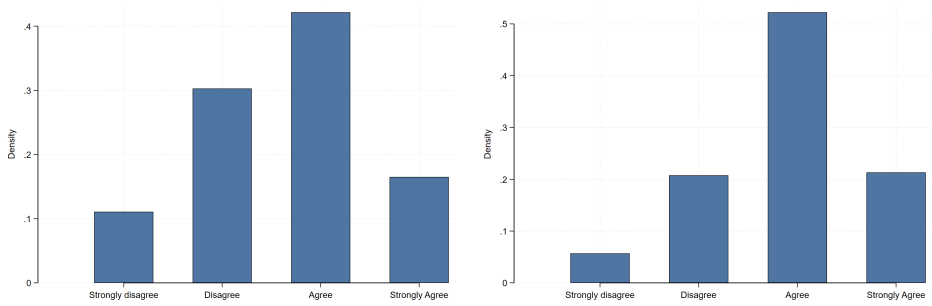
Figure 8. The distribution of the self-efficacy index



Notes: *The self-efficacy index is constructed with factor analysis using answers to the nine questions reported in Table 1.*

Finally, we focus on the most important outcome variable in our empirical analysis, namely the students perceived learning loss during the pandemic. To capture this outcome, we utilized a question that asked our students whether they learned as much in remote learning classes as they would have in traditional face-to-face lessons.

Figure 9. Remote versus in-presence school: the students' learning perception



(a) I learned as much as I would have in presence

(b) I got similar grades at school

Notes: *In Panel (a), students answer how much they agree to the following statement: "During RL, I learned about as much as I would have by going to school". In panel (b) they answer how much they agree with the statement: "The grades that I get are similar to those I would get in presence." All answers relate to all the school activities offered from September onward.*

Figure 9 Panel (a) shows that a significant portion of the students, 43%, felt that RL negatively impacted their learning opportunities, while just over half (57%) disagreed with this statement. We also asked students if the grades they received during remote learning assessments were similar to those they would have received

in an in-person setting. Figure 9 Panel (b) indicates that the majority of students (about two-thirds) believe their grades remained consistent with what they would have received during face-to-face schooling. In summary, evidence from both panels (a) and (b) suggests that, during the pandemic, the mapping between grades and learning has changed. It is likely that, due to the pandemic, teachers assessed students less strictly. However, we cannot rule out that it was easier for students to cheat, as 70% of them also reported that it was easier to get hints or copy during RL.

4 Pandemic, remote learning and inequality patterns

This section explores the evolution of inequalities during the pandemic along different dimensions, examining the presence of unequal results across different types of students and upper secondary schools, and finally investigating potential patterns of territorial heterogeneity.

We start by analyzing the most sensitive dimension from a policy perspective: the presence of differentiated patterns in various student outcomes during the second lockdown among more and less vulnerable students. Table 2 explores the heterogeneity in perceived learning loss between high and low SES students. Here, we define high-SES students as those who have values of the deprivation index, described in Section 3.3 below the median (see also Figure 7). Conversely, students with values above the median, are identified as low-SES. This Table shows that high-SES students perceived a lower learning loss during the second lockdown and felt that their grades were more consistent with in-person schooling than more vulnerable or low-SES students. The difference between the two groups is also statistically significant.

Table 2. Students' perceptions of RL consequences by SES

	Low deprivation	High deprivation	Difference
I learned as much as I would have in presence	2.816	2.475	0.341***
I got similar grades as I would have in presence	3.001	2.790	0.211***

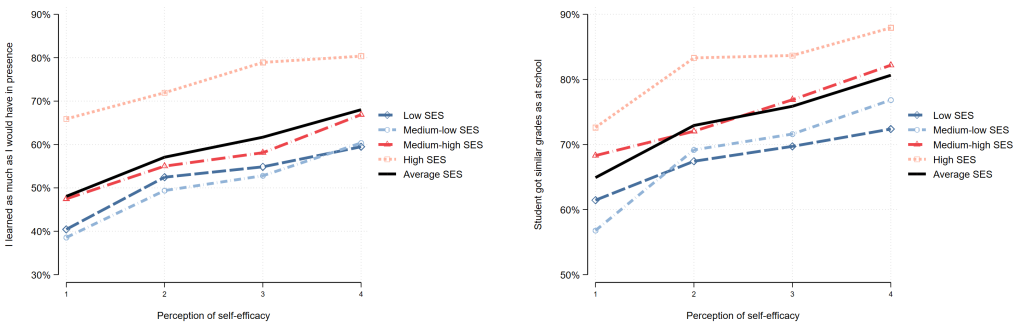
Notes: *Students had to indicate how much they agreed with each statement using the following scale: 1-Strongly disagree, 2-Disagree, 3-Agree, 4-Strongly Agree. Students are also classified as experiencing low/high deprivation if their deprivation index score falls below/above the median of the distribution. The t-test of equal means reported with significance levels identified by * 10%, ** 5%, *** 1%.*

To ease the interpretation, in the following, we use a simple linear transformation of the deprivation index and obtain an index where high/low values of the new index represent high-SES/low-SES students.[29] In Figure 10 panel (a), we combine

[29]We multiply the deprivation index by -1. In this case, higher values that represented greater

perceived learning losses with this SES index and the self-efficacy index, dividing the latter indices into quartiles. This allows us to summarize the overall relationship among these three student characteristics. We identify significant heterogeneity among different types of students in terms of learning loss perceptions: the perception of learning differences between schools in presence and RL activities is, again, higher for low-SES and also for students with lower values of the self-efficacy index.

Figure 10. Inequality patterns at student's level



Notes: *The Y axis of panel (a) measures the % of students who agreed or strongly agreed with the statement: "During RL, I learned about as much as I would have by going to school". The Y axis of panel (b) measures the % of students who agreed or strongly agreed with the statement: "The grades that I get are similar to those I would get in presence." All answers relate to all the school activities offered from September onward. Both the SES index and the self-efficacy indexes are divided into quartiles. The different colored dashed lines identify the different SES quartiles, while the black continuous line identifies the average.*

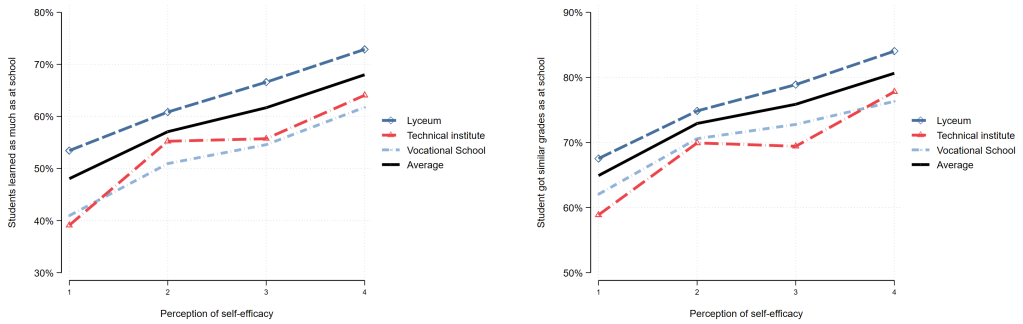
We observe similar heterogeneity patterns in panel (b), which focuses on the perception of grading practices during online schooling. Here, the percentage of students who perceived their grades to differ during RL is lower among high-SES and high self-efficacy students.

Next, we replicate the analysis by replacing the student's socio-economic status index with the type of school they attend. As mentioned earlier, the Italian educational system offers three main options: general or academic (Licei), technical (Istituti Tecnici), and vocational (Istituti Professionali) schools. This initial sorting often results in social tracking, with students in general/academic tracks typically coming from higher socio-economic status families and achieving higher educational outcomes than those in vocational tracks.

Figure 11 shows that students enrolled in Lyceums have a lower perception of learning loss compared to those in technical or vocational schools. This confirms the presence of school segregation in the Italian upper secondary school system and

deprivation will now become lower values of wealth, and vice versa.

Figure 11. Inequality patterns: the school type



Notes: *The Y axis of panel (a) measures the % of students who agreed or strongly agreed with the statement: "During RL, I learned about as much as I would have by going to school". The Y axis of panel (b) measures the % of students who agreed or strongly agreed with the statement: "The grades that I get are similar to those I would get in presence." All answers relate to all the school activities offered from September onward. The self-efficacy index is divided into quartiles. The different colored dashed lines identify the different types of schools the students attend, while the black continuous line identifies the average.*

fully corroborates previous findings on the growing inequalities.

Finally, we examine potential territorial heterogeneity patterns. The geographical location of schools is a significant determinant of educational outcomes in Italy, with students in the Northern regions generally outperforming those in the South (Bratti et al., 2007; Cipollone et al., 2010; Di Liberto, 2008).

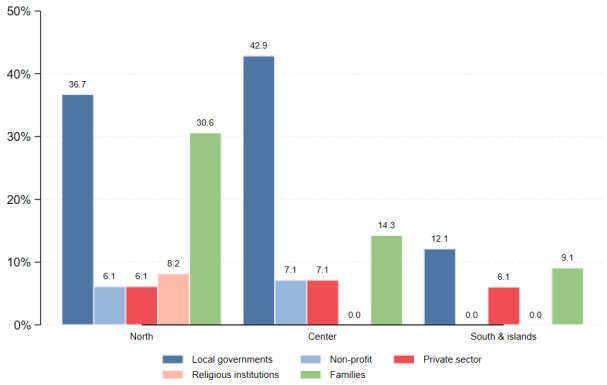
We first replicate the previous analysis, substituting school type with geographical location (North, Centre, and South-Islands) and do not find significantly different patterns across the different areas.[30] Second, using the principals' responses, we investigate the territorial heterogeneity in school resources. Specifically, our survey inquired whether schools received additional funding during the second lockdown to address remote learning challenges, apart from government funding. Figure 12 shows the proportions of schools that received financial support from various stakeholders (local governments, the third sector, private sector, religious organizations, or families) across different regions.

This evidence suggests that additional funds were predominantly allocated to wealthier regions, with schools in the South, the less developed area of the country, receiving fewer resources compared to other areas. However, compared to other areas, our South sample is more biased towards more advantaged schools than the other macro-region samples. Thus, all the evidence on macroarea heterogeneity needs to be taken with caution.[31] Thus, we leave the critical issue of territorial

[30] On this see Figure A2

[31] See Section 3 and Table A4 in the Appendix for more details.

Figure 12. External schools' funds received during the second lockdown



Notes: *This chart analyzes the distribution of financial support for schools across three different areas: North, Centre, and South Islands. Data are based on the principals' answers on the level of support their schools received during the lockdown in addition to the state funding from the local governments, the third sector, the private sector, religious organizations, and families.*

inequality patterns on both students results and additional funds received by schools to further investigation.

5 Results

To further investigate the relationship between school outcomes during RL we will employ a simple cross-section OLS model. Our main focus is on the role of teaching practices adopted during online syncronous activities, but we also include in our analysis the many covariates we have collected in our three-level survey to isolate the partial correlation between $TEACH_{ij}$ and a list of additional important determinants. The regression model takes the form:

$$Y_{ij} = \alpha + \beta TEACH_{ij} + \gamma X_{ij} + \delta Z_j + \upsilon_{ij} \tag{1}$$

where Y_{ij} represent an outcome variable of student i attending school j, X_{ij} and Z_j are vectors of individual student controls and school controls, respectively; and the variable $TEACH_{ij}$ represents the teachers' innovation index. Moreover, to take into account the area fixed characteristics, including the differences in the length of in-person schooling across the different areas during the second lockdown, all regression models always adds area dummies at the NUTS3 level.[32] Finally,

[32]To control for the oversampling of specific areas as described in Section 3, we replicate the analysis using sampling weights to reflect the proportions observed in the population. Excluding the sampling weights from the analysis does not change the results.

since students' responses to different classroom activities refer to one of four specific subjects (randomly allocated as described in section 3.3), we also include dummy variables for the different subjects.

Table A5 presents the results obtained using our most important dependent variable, which reflects student agreement with the statement, "During RL, I learned about as much as I would have by going to school." This variable is a dummy equal to one for students who agree or strongly agree with this statement. Estimates are obtained using a Linear Probability Model, with standard errors clustered at the school level.[33]

Column one presents the results of the most parsimonious specification, including only our main variable of interest, $TEACH_{ij}$, the teaching innovation index calculated from student responses regarding specific teaching methodologies adopted during the prolonged online learning periods. We further explore the relationship between students' perceived learning loss due to RL by including additional variables from our survey that may have influenced remote learning activities. Models 2 to 4 include student characteristics (the deprivation index, their perception of self-efficacy, grade retention, and a dummy identifying 11th graders) and the type of upper secondary school attended. Models 5 and 6 incorporate two variables from the school principals' survey, namely, the absence of changes in the school organization during the RL periods, and the additional school funds received. These two additional controls are, as done before, computed as synthetic indexes using factor analysis. For the former, we include variables such as the average daily hours spent in online learning, the changes in the distribution of subjects in the timetable, and the duration of each lesson. For the latter, we introduce the funds received from various stakeholders as illustrated in Figure 12.

[33]We use LPM for its robustness as observed by Angrist and Pischke (2009). However, the use of a Logit estimator yields the same results.

Table 3. Perception of learning during RL

Dep. var.: *I learned as much as I would have in presence (yes=1)*						
	(1)	(2)	(3)	(4)	(5)	(6)
Innovation index	0.0569***	0.0564***	0.0429***	0.0482***	0.0522***	0.0516***
	(0.00830)	(0.00765)	(0.00700)	(0.00705)	(0.00785)	(0.00796)
Deprivation index		-0.0838***	-0.0807***	-0.0777***	-0.0818***	-0.0814***
		(0.00714)	(0.00700)	(0.00685)	(0.00721)	(0.00722)
Perception of self-efficacy			0.0725***	0.0721***	0.0719***	0.0719***
			(0.00603)	(0.00616)	(0.00704)	(0.00703)
Grade retention (%)				-3.027***	-2.735***	-2.352**
				(0.923)	(0.855)	(0.912)
Grade 11				0.0666***	0.0835***	0.0829***
				(0.0144)	(0.0150)	(0.0150)
Technical school				-0.0770***	-0.0545***	-0.0540***
				(0.0269)	(0.0187)	(0.0189)
Vocational School				-0.0962***	-0.101***	-0.106***
				(0.0196)	(0.0239)	(0.0230)
School size				-0.000854	0.00325	0.00282
				(0.00392)	(0.00248)	(0.00230)
No organizational changes					-0.0247	-0.0392*
					(0.0235)	(0.0231)
Additional school funds						0.0454*
						(0.0252)
Area dummies	yes	yes	yes	yes	yes	yes
School subjects dummies	yes	yes	yes	yes	yes	yes
Observations	9360	9345	9320	9297	7506	7506
Adjusted R^2	0.026	0.044	0.061	0.071	0.075	0.075
Number of schools	87	87	87	87	71	71

Notes: *The dependent variable measures the learning loss during RL as perceived by students. Standard errors in parentheses are clustered at the school level. * p<0.10, ** p<0.05, *** p<0.01.*

Except for school size, most variables are significant and show the expected signs. Students' socioeconomic level and grade retention negatively correlate with the perception of learning during RL, while self-efficacy perception has a positive sign. Compared to 13th graders, younger students perceived having learned more during RL. With Lyceum as the reference category, as expected, technical and vocational school coefficients have negative signs. When including the additional variables from school principals in models 5 and 6, we observe a reduction in sample size but no change in the sign and significance of these variables. The variable measuring the absence of innovations in school organization during synchronous teaching activities (e.g., using the same timetable, lesson length, and number of RL hours) negatively correlates with students' learning perception, while additional funding

shows a positive sign. Notably, the teaching innovation index consistently shows a positive relationship with students' perceived performance during RL. As a final robustness check, we have also estimated models from 1 to 4 including school fixed effects finding no significant differences in the coefficients of all included variables.

Table A6 further investigates these relationships using an ordered logit model that exploits the ranking nature of our dependent variable.[34] Table A6 shows the marginal effects for the different degrees of agreement or disagreement of the dependent variable, along with standard errors for three main covariates: the teachers' innovation Index, the Deprivation Index, and the self-efficacy index. The regression includes all the additional controls of model 4 Table A5 with standard errors clustered at the school level.

Table 4. Perception of learning during RL: ordinal logit

Dep. var.: *I learned as much as I would have in presence*	Innovation index	Deprivation index	Perception of self-efficacy
Strongly disagree	-0.0195***	0.0341***	-0.0345***
	(0.00293)	(0.00283)	(0.00305)
Disagree	-0.0281***	0.0493***	-0.0497***
	(0.00422)	(0.00408)	(0.00440)
Agree	0.0206***	-0.0360***	0.0364***
	(0.00309)	(0.00298)	(0.00322)
Strongly Agree	0.0270***	-0.0474***	0.0478***
	(0.00406)	(0.00392)	(0.00423)
Observations	9297		
Number of schools	87		
Log likelihood	-1083766.4		
Pseudo R2	0.0420		

Notes: *Additional controls include grade retention, a dummy for 11th graders, school size, and types of school and subject dummies. See notes on Table A5 for details on the dependent variable. Standard errors in parentheses are clustered at the school level. * p<0.10, ** p<0.05, *** p<0.01.*

Our dependent variable reflects students' agreement with the statement "During RL, I learned about as much as I would have by going to school" on a 4-point Likert Scale, with choices: Strongly Disagree, Disagree, Agree, or Strongly Agree. Results in column one indicate that a one-unit increase in the teaching innovation index decreases the probability of being in the "strongly disagree" category by 2 percentage points while increasing the probability of "strongly agree" by 2.7 percentage points, on average, holding other factors constant. Similar trends are observed for the self-efficacy index and the deprivation index, with the latter showing the expected

[34]The ordered logit model is estimated using Stata's feologit function Baetschmann et al. (2020). This model assumes independent and identically distributed error terms. We employed the efficient blow-up and cluster (BUC) estimator for model fitting. In this estimation, we do not include variables at the principal school level, as the estimator accounts for school fixed effects.

opposite signs.

Table A7 presents the results when using alternative students outcome variables while including the same set of control variables as model 6 Table A5. The survey gathered students' assessments of their overall online learning experience, including their interactions with teachers and classmates. We expect that these perceptions are influenced by the implementation of online teaching, thus correlating with our measure of innovative teaching and other covariates.

The first new dependent variable, *Student RL Engagement*, is a dummy equal to one for students who agree or strongly agree with the statement: "Teachers had us experience new teaching methods during online learning, which I greatly appreciated." The second variable, *Wish for RL to continue*, is similarly calculated based on the statement: "I would like the use of digital platforms and learning apps to continue once we return to school after the COVID emergency."[35] The third outcome variable, *RL efficacy* (model 3), tries to capture whether students found it easier to interact with teachers during remote learning compared to in-person learning. Again, factor analysis is applied using the students' responses to the following statements: 1) intervening during online lessons is easier than during face-to-face schooling, 2) teamwork activities are easier, and 3) getting in touch with professors online is easier than in person.

[35] As above, these variables describe students' agreement on a 4-Point Likert Scale: Strongly Disagree, Disagree, Agree, or Strongly Agree.

Table 5. Alternative students' outcome variables

Dep. var.:	*Student RL Engagement*	*Wish for RL to continue*	*RL efficacy*
	(1)	(2)	(3)
Innovation index	0.150***	0.0459***	0.0841***
	(0.00907)	(0.00772)	(0.0108)
Deprivation index	-0.0673***	-0.0536***	-0.0846***
	(0.00764)	(0.00686)	(0.0147)
Grade retention (%)	-0.325	0.215	-4.349**
	(0.892)	(0.616)	(1.692)
Grade 11	0.0804***	0.0544***	0.163***
	(0.0174)	(0.0152)	(0.0264)
Technical school	0.0740***	0.0620***	0.234***
	(0.0223)	(0.0159)	(0.0420)
Vocational School	0.119***	0.0162	0.261***
	(0.0236)	(0.0221)	(0.0442)
School size	-0.00361	0.00269	0.00100
	(0.00252)	(0.00208)	(0.00466)
No organizational changes	-0.0448	-0.0585***	0.0304
	(0.0301)	(0.0168)	(0.0372)
Additional school funds	0.0460*	-0.0274	0.0799**
	(0.0241)	(0.0216)	(0.0349)
Area dummies	yes	yes	yes
School subjects dummies	yes	yes	yes
Observations	7528	7528	7528
Adjusted R^2	0.109	0.022	0.070
Number of schools	71	71	71

Notes: *Additional controls include grade retention, a dummy for 11th graders, school size, and types of school and subject dummies, the absence of changes in the school organization during the RL periods, and the additional school funds received. See notes on Table A5 for details on the dependent variable. Standard errors in parentheses are clustered at the school level. * p<0.10, ** p<0.05, *** p<0.01.*

Overall, the results in Table A7 confirm that teaching methodologies deemed more suitable and effective for online learning are consistently positively correlated not only with perceived student learning but also with a better RL experience, a desire to continue using online activities post-pandemic, and the perception of greater effectiveness in specific activities and interactions.

Finally, given its policy relevance, we explore the relationship between our main variable of interest, $TEACH_{ij}$ (which quantifies the extent of innovative teaching methodologies used in class during RL), and additional key factors likely to influence it. Among these factors, training in digital skills stands out as crucial, as it likely affected teachers' ability and willingness to adopt more appropriate teaching methods during RL. Our surveys identify two distinct variables measuring teachers' training activities during the pandemic. The first is derived from the school principals' survey, as described in Figure 2. It reflects the principals' perceptions

of teachers' training needs during the second lockdown. Here, a higher value of the variable indicates a greater necessity for ICT instructional support for teachers. The second variable is self-reported by the interviewed teachers. We use their responses, as shown in Figure 3, which describe the intensity of the training received by teachers in different ICT areas during the pandemic. For each teacher, we calculate the average percentage of answers reporting of not having received any training in each area during the lockdown. For both variables, the expected sign is negative, which would indicate a negative correlation between a greater need for training (in the first case) or less training received (in the second case) and the level of innovative teaching that occurred in the classroom.

Table 6. Teachers' training and innovative teaching methodologies

Dep. Var: *Innovative teaching index*		
	(1)	(2)
Teachers low digiskills (School principals' survey)	0.0518	
	(0.0400)	
No digiskills training (Teachers' survey)		-0.517*
		(0.277)
Area dummies	yes	yes
School subjects dummies	yes	yes
Observations	7521	7521
Adjusted R^2	0.127	0.128
Number of schools	71	71

Notes: *The dependent variable is the innovative teaching index as described in Figure 6. Additional controls include grade retention, a dummy for 11th graders, school size, and types of school and subject dummies, the absence of changes in the school organization during the RL periods, and the additional school funds received. Standard errors in parentheses are clustered at the school level. * p<0.10, ** p<0.05, *** p<0.01.*

Table A8 introduces the innovative teaching index as the dependent variable. To save on space, Models 1 and 2 only show the results for the two alternative teacher training variables.[36] In model 1, using principals' perceptions of teachers' digital training needs, the coefficient is not significant. In model 2, the intensity of training received by teachers during RL shows the expected negative and significant coefficient.

6 Final discussion

Recent global events have forced schools to significantly reorganize their activities and adopt new learning models. There is now widespread evidence that school closures and the sudden adoption of alternative teaching methods have negatively

[36]The full list of additional regressors is described in the notes of Table A8, with results available upon request.

impacted student learning outcomes. However, the reasons and mechanisms behind these outcomes have yet to be thoroughly investigated.

This study aims to examine the extent to which Italian schools employed new teaching practices during remote learning, how they reorganized their activities, and how these changes influenced students' perceived results. Specifically, the focus is on upper secondary Italian schools and their closure during the second pandemic period starting in September 2020. Our results are derived from a unique three-level survey that collects the perceptions of a large sample of students, teachers, and school principals. Although it did not allow for a causal empirical study, our rich dataset enabled us to produce a large set of descriptive evidence that examines some key mechanisms likely to explaing the presence of learning loss during the pandemic and provides useful insights.

The results strongly suggest that, despite government guidelines recommending innovation in online teaching, the training offered to teachers, and the experience gained by schools during the first lockdown from March to June 2020, most Italian principals and teachers were still unfamiliar with the tools and approaches appropriate for remote education. Specifically, most interviewed teachers adopted online teaching modalities that closely resembled traditional face-to-face learning environments. Despite this, a large proportion of teachers perceived their digital skills as adequate to handle online teaching during COVID. Additionally, the organization of remote school activities underwent few modifications compared to what would have been appropriate in a distance learning situation. In most cases, the organization of school time and activities during remote learning was merely an online transposition of in-person school hours, without significant reorganization. Poor digital skills and inadequate training appeared to be plausible reasons for the choices made during distance learning.

When we focus on inequality patterns, our descriptive statistics suggest an increase in disparities during the school closure: the students' perception of learning loss due to online activities compared to in-person schooling was higher among more vulnerable students (those with lower socioeconomic status and self-efficacy). This is also confirmed by the separate analysis by type of schools. Indeed, the Italian upper secondary school track implies that more fragile students are more likely to attend technical or vocational schools: these students perceived they learned less during remote learning compared to their peers enrolled in Lyceums. Thus, if this COVID-induced perception of learning losses persists over time, it might influence subsequent educational choices and further increase the already high existing educational inequalities in Italy.

Our regression results fully corroborate the previous evidence of non-homogeneous effects on students' learning and offer new insights. First, conditional on observable students' and schools' characteristics, we find a robust positive correlation between the students' perception of learning and the use in class of innovative online teach-

ing methods and a negative one with the variable identifying schools that did not change their organization of activities during remote learning. Second, the use of teaching methodologies deemed more suitable and effective for online learning is also consistently positively correlated with alternative student outcomes, such as the perception of a better remote learning experience, the desire to continue using online activities even after the pandemic, and the perception of its efficacy and the quality of interactions during the activities. Finally, we find that the intensity of innovative teaching is positively and significantly correlated with the intensity of the teachers' training offered during the pandemic.

The surveys also investigate the legacy of this COVID-19 experience, and whether it opened up new teaching perspectives in the Italian educational system. We asked teachers and school principals about the expected impact of the COVID emergency on two important outcomes: teachers' digital skills, and the use of digital distance learning in the Italian educational system. A large percentage of both groups argued that the trend toward using ICT in Italian schools prompted by the pandemic was here to stay. Almost all school principals (89%) and 71% of teachers believe that the COVID emergency had a positive effect on the growth of teachers' skills in their schools. Similar outcomes, with teachers always relatively less optimistic, were found when the question extended to other schools. When asked whether digital teaching will be adopted as a complement to face-to-face schooling in the future, three out of four school principals believe it is probable that online schooling will be adopted in the future both in their own schools and in the Italian school system.

Despite these optimistic believes, these predictions have not materialized so far. Unlike remote work, where the pandemic led to both an immediate surge and a sustained increase in working from home, the shift to remote learning during the pandemic has not produced a similar pattern of ICT adoption in schools. Instead, schools have largely reverted to traditional methods. Additionally, this evidence comes from a large and heterogeneous sample of schools, which, compared to the overall population of Italian schools, is somewhat biased towards those with more motivated teachers and students with higher SES and better academic results. If anything, we expect that a balanced sample of the population would have shown even less use in class of the most effective online teaching methods.

Overall, our investigation suggests that the Italian government did not do enough to incentivize continuous, lifelong investment in teachers' training to ensure their digital skills were up-to-date before the COVID shock, while the training offered during the epidemic was most likely not effective and was not implemented with homogeneous standards across Italian schools. This further suggests that the government could have better coordinated activities or, at least, promoted more effectively the dissemination of best practices in online learning. This study stresses the importance of rethinking how teacher training policies are implemented in a country like Italy, which has the oldest teaching workforce among European countries alongside

students' academic performance below the EU average. In this context, it is crucial to consider lifelong learning for teachers regarding innovative teaching practices and new technologies. As mentioned, the COVID-19 experience does not seem to have left a profound mark on Italian schools, which struggled to use innovative methodologies during remote learning and quickly reverted to traditional teaching methods afterward.

In conclusion, this analysis provides a framework to understand the implications of the pandemic experience as lived by the schools of a large EU economy, offering a solid basis for further research and food for thought for future studies. Our evidence is relevant not only to the debate on effective strategies to mitigate the effects of the COVID-19 shock on education, but it also provides insights into long-term issues related to the adoption of future innovations in the educational sector. Technological changes are deeply transforming not only workplaces but also the education sector. In a period of rapid and pervasive technological change, with AI rapidly entering our daily lives, teaching innovations may be a powerful tool for improving students' outcomes and educational opportunities. This demands new skills, and equipping teachers with the necessary digital skills should be seen as a strategic policy to enable students to thrive in a continuously changing environment and a necessary tool to reduce inequalities.

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A Appendix

A.1 Data collection and sample balance

The data collection was administered during the second wave of the Covid-19 pandemic by the Crenos Studies Center and the Department of Economics and Business of the University of Cagliari, together with the Agnelli Foundation, during the period March-June 2021.

We randomly selected 5% of upper secondary schools within each Italian macroarea (NUTS 1), stratified by four school types (Lyceum, Technical Institute, Vocationa Schools, *Istituti Superiori*). Schools were firstly contacted via e-mail with a presentation letter of the study, followed by a phone call to the School Principal. After acceptance, the links of the three questionnaires within the platform Survey Monkey were sent via e-mail to the school. In case of refusal to participate, we randomly picked a second school with the same characteristics. This happened in 38% of cases and we never went beyond the 3rd substitution.

As an incentive mechanism to boost students' participation in the survey and lessen selection issues, we decided to give away 500 Amazon vouchers (of 20€ value) to be extracted among the students who completed the questionnaire.

Below, we compare the characteristics of our sample with those of the population using the information collected from the dataset "La scuola in chiaro" from the Italian Ministry of Education.

Table A1. Sample balance

	Sample		Population	
	N. of schools	% of schools	N. of schools	% of schools
North	83	50.9	1931	36.9
Center	24	14.7	1007	19.2
South	56	34.4	2299	43.9
Lyceum	69	42.3	2063	39.4
Technical institute	56	34.4	1827	34.9
Vocational School	38	23.3	1347	25.7
Total	163	100	5237	100

Note: Macroareas include the following regions. North: Emilia-Romagna, Friuli-Venezia Giulia, Liguria, Lombardy, Piedmont, Veneto and Trentino. Center: Lazio, Marche, Tuscany and Umbria. South: Abruzzo, Apulia, Basilicata, Calabria, Campania, Molise, Sicily and Sardinia.

Table A2. Descriptive statistics

Sample data	Mean	Standard Deviation	Min	Max	Obs.
Outgoing students	0.017	0.014	0	0.065	155
Incoming students	0.010	0.018	0	0.13	157
Dropout	0.0038	0.0084	0	0.060	155
Grade retention	0.0049	0.010	0	0.063	159
Population data	**Mean**	**Standard Deviation**	**Min**	**Max**	**Obs.**
Outgoing students	0.019	0.032	0	0.56	5448
Incoming students	0.017	0.048	0	0.75	5747
Dropout	0.0057	0.016	0	0.24	5448
Grade retention	0.0087	0.024	0	0.53	5722

Note: Variables are expressed as a ratio of the total.

Here we investigate the presence of any differences across different school types, and among different areas of the country (North, Central, and South & Islands).

Table A3. Descriptive statistics by group

	Lyceum		Technical institute		Vocational School	
	Sample	Population	Sample	Population	Sample	Population
Outgoing students	0.016	0.015	0.016	0.017	0.019	0.018
	(0.013)	(0.014)	(0.013)	(0.018)	(0.015)	(0.021)
Incoming students	0.0071	0.0059	0.0097	0.0093	0.014	0.011
	(0.019)	(0.0099)	(0.012)	(0.015)	(0.024)	(0.017)
Dropout	0.0016	0.0030	0.0036	0.0047	0.0065	0.0100
	(0.0041)	(0.0072)	(0.0072)	(0.011)	(0.012)	(0.019)
Grade retention	0.0011	0.0029	0.0049	0.0068	0.0098	0.016
	(0.0025)	(0.0072)	(0.0092)	(0.014)	(0.015)	(0.028)

Table A3 disentangles the information for the three different types of schools: Lyceums, Technical, and Vocational schools. The data on dropouts indicates the percentage of students who have discontinued school attendance during the school

year. With few exceptions, the reported shares of both dropouts and grade retention rates suggest the presence of a selection of the best for each type of school.

Table A4. Descriptive statistics by area

	North		Center		South	
	Sample	Population	Sample	Population	Sample	Population
Outgoing students	0.018	0.017	0.017	0.018	0.014	0.015
	(0.013)	(0.018)	(0.015)	(0.017)	(0.014)	(0.016)
Incoming students	0.0075	0.0065	0.015	0.0094	0.0096	0.0095
	(0.0086)	(0.0098)	(0.024)	(0.015)	(0.022)	(0.016)
Dropout	0.0056	0.0052	0.0014	0.0048	0.0037	0.0056
	(0.010)	(0.011)	(0.0033)	(0.012)	(0.0085)	(0.014)
Grade retention	0.0042	0.0043	0.0041	0.0081	0.0069	0.0098
	(0.0088)	(0.0094)	(0.0085)	(0.018)	(0.014)	(0.022)

Table A4 investigates the presence of heterogeneity among different areas of the country (North, Central, and South & Islands). Again, numbers indicate the presence of a selection bias favoring schools with better academic results compared to the population but not in all areas. Specifically, this positive selection is observed in schools in the central regions and even more so in the South and Islands. On the one hand, the sample shares on grade retention reported in Table A4 still confirm the lower educational outcomes of our southern school sample compared to those in other areas of the country. Nevertheless, it also stresses that the percentages of dropouts and grade retention in the Centre and South of Italy are significantly lower than those observed in the population. Conversely, in the North the sample's characteristics are similar to those observed in the population.

A.2 Estimates with No weights

Table A5. Perception of learning during RL

Dep. var.: *I learned as much as I would have in presence (yes=1)*						
	(1)	(2)	(3)	(4)	(5)	(6)
Innovation index	0.0538***	0.0540***	0.0411***	0.0469***	0.0497***	0.0493***
	(0.00641)	(0.00602)	(0.00561)	(0.00552)	(0.00609)	(0.00614)
Deprivation index		-	-	-	-	-
		0.0892***	0.0853***	0.0826***	0.0880***	0.0878***
		(0.00674)	(0.00672)	(0.00660)	(0.00679)	(0.00680)
Perception of self-efficacy			0.0729***	0.0712***	0.0700***	0.0700***
			(0.00508)	(0.00492)	(0.00541)	(0.00540)
Grade retention (%)				-2.541***	-2.413***	-2.119**
				(0.955)	(0.779)	(0.847)
Grade 11				0.0735***	0.0898***	0.0896***
				(0.0137)	(0.0146)	(0.0146)
Technical School				-	-	-
				0.0975***	0.0580***	0.0586***
				(0.0309)	(0.0187)	(0.0189)
Vocational School				-0.103***	-0.101***	-0.105***
				(0.0230)	(0.0277)	(0.0280)
School size				-0.00165	0.00378	0.00344
				(0.00421)	(0.00236)	(0.00235)
No organizational changes					-0.0311	-0.0378*
					(0.0201)	(0.0213)
Additional school funds						0.0225
						(0.0251)
Observations	9360	9345	9320	9297	7506	7506
Adjusted R^2	0.023	0.043	0.060	0.073	0.075	0.075
Number of schools	87	87	87	87	71	71

Notes: *The dependent variable measures the learning loss during RL as perceived by students. Standard errors in parentheses are clustered at the school level. * p<0.10, ** p<0.05, *** p<0.01.*

Table A6. Perception of learning during RL: ordinal logit

Dep. var.: *I learned as much as I would have in presence*	Innovation index	Deprivation index	Perception of self-efficacy
Strongly disagree	-0.0192***	0.0365***	-0.0345***
	(0.00227)	(0.00273)	(0.00241)
Disagree	-0.0277***	0.0527***	-0.0498***
	(0.00328)	(0.00394)	(0.00348)
Agree	0.0203***	-0.0386***	0.0365***
	(0.00240)	(0.00289)	(0.00255)
Strongly agree	0.0266***	-0.0507***	0.0479***
	(0.00315)	(0.00379)	(0.00335)
Observations	9297		
Number of schools	87		
Log likelihood	-12230.7		
Pseudo R2	0.0434		

Notes: *Additional controls include Grade retention, Grade 11, Technical school, Vocational School, School size and both type of school and subject dummies. The dependent variable is the student answer to the statement: "When you think about the lessons and other activities that have been offered to you from September onward, how much do you agree with the following statements? I learned about as much as I would have learned by going to school? Please indicate how much you agree with the following statements using the following scale: 1-Strongly disagree, 2-Disagree, 3-Agree, 4-Strongly Agree". Standard errors in parentheses are clustered at the school level. * p<0.10, ** p<0.05, *** p<0.01.*

Table A7. Alternative students' outcome variables

	(1) Student RL Engagement	(2) Wish for RL to continue	(3) RL efficacy
Innovation index	0.144***	0.0492***	0.0855***
	(0.00781)	(0.00620)	(0.0102)
Deprivation index	-0.0684***	-0.0550***	-0.0891***
	(0.00602)	(0.00628)	(0.0151)
Grade retention (%)	-0.205	0.363	-3.532*
	(0.764)	(0.628)	(1.840)
Grade 11	0.0802***	0.0473***	0.156***
	(0.0158)	(0.0135)	(0.0213)
Technical School	0.0668***	0.0706***	0.230***
	(0.0213)	(0.0132)	(0.0302)
Vocational School	0.117***	0.0171	0.256***
	(0.0237)	(0.0186)	(0.0360)
School size	-0.00337	0.00203	-0.000507
	(0.00244)	(0.00244)	(0.00401)
No organizational changes	-0.0480*	-0.0436**	0.0595
	(0.0267)	(0.0177)	(0.0376)
Additional school funds	0.0496**	-0.0178	0.0826**
	(0.0242)	(0.0230)	(0.0395)
Observations	7528	7528	7528
Adjusted R^2	0.102	0.023	0.070
Number of schools	71	71	71

Notes: *Standard errors in parentheses are clustered at the school level. * p<0.10, ** p<0.05, *** p<0.01.*

Table A8. The teacher innovation index

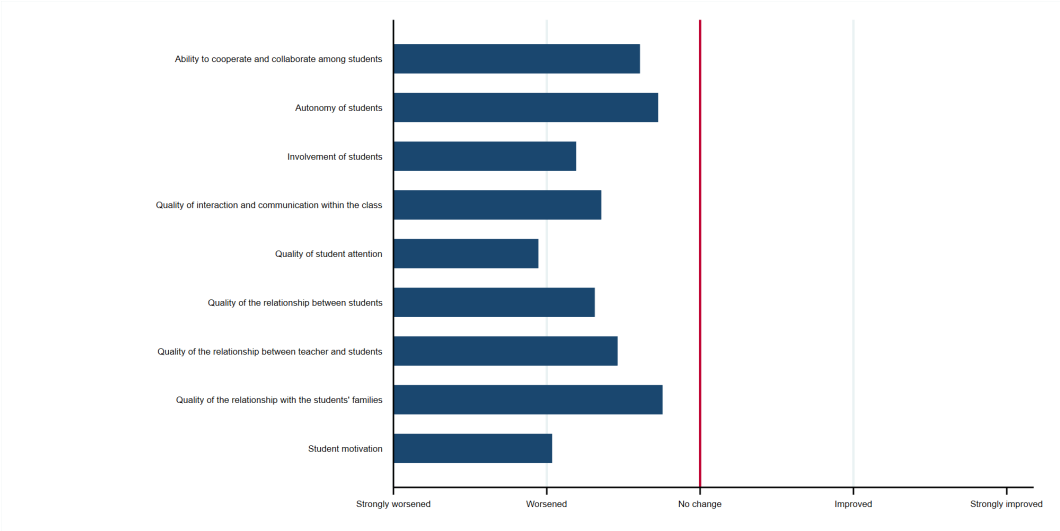
Dep. Var: *Teacher innovation index*	(1)	(2)
Additional school funds	0.151**	0.136**
	(0.0604)	(0.0613)
No digiskills training (Teachers' survey)		-0.260
		(0.220)
Teachers low digiskills (School principals' survey)	0.0370	
	(0.0357)	
No organizational changes	0.106*	0.0775
	(0.0598)	(0.0576)
Observations	7521	7521
Adjusted R^2	0.112	0.112
Number of schools	71	71

Notes: *The dependent variable measures the innovativeness of the teaching practice. The analytical unit is the individual student, and we establish connections between their responses, the feedback from school principals, and that of the Ministry of Education for each school in which the students are enrolled. We control for Deprivation index, Self-efficacy, Technical school, Vocational School and School size. Standard errors in parentheses are clustered at the school level. * p<0.10, ** p<0.05, *** p<0.01.*

A.3 Additional evidence

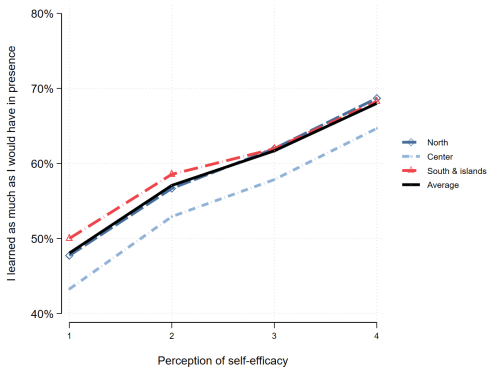
Remote learning affected students' habits, increasing challenges with focus and engagement. Many experienced more fatigue and found it harder to stay attentive compared to in-person classes. Frequent changes in school organization were disruptive, and some struggled with the lack of a quiet place to study. Few found it easier to interact with teachers online, though some felt more comfortable asking questions. The absence of face-to-face interaction and classroom socialization were also key issues. The teachers confirm the perception of their students and believe that the RL has caused significant deterioration along a whole series of relevant dimensions of the relationship among school actors (students, teachers, and families).

Figure A1. RL and dimensions of the relationship among school actors



Finally, we examine potential territorial heterogeneity patterns in learning. The geographical location of schools is a significant determinant of educational outcomes in Italy, with students in the Northern regions generally outperforming those in the South. When we replicate the analysis of section 4, dividing by schools' geographical location (North, Centre, and South-Islands) we do not find significantly different patterns.

Figure A2. Remote vs in-presence school: the students' learning perception (by areas)



Notes: *The Y axis measures the % of students who agreed or strongly agreed with the statement: "During RL, I learned about as much as I would have by going to school". All answers relate to all the school activities offered from September onward. The self-efficacy index is divided into quartiles. The different colored dashed lines identify the different areas the school belongs to, while the black continuous line identifies the average.*