



HAL
open science

A systematic review and meta-analysis of the impact of the COVID-19 pandemic on learning

Bastian Betthäuser, Anders Bach-Mortensen, Per Engzell

► To cite this version:

Bastian Betthäuser, Anders Bach-Mortensen, Per Engzell. A systematic review and meta-analysis of the impact of the COVID-19 pandemic on learning. *Nature Human Behaviour*, 2023, 10.1038/s41562-022-01506-4 . hal-03954706

HAL Id: hal-03954706

<https://sciencespo.hal.science/hal-03954706>

Submitted on 24 Jan 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

A systematic review and meta-analysis of the impact of the COVID-19 pandemic on learning

Bastian A. Betthäuser¹⁻⁴, Anders M. Bach-Mortensen³, Per Engzell⁴⁻⁶

How has the COVID-19 pandemic affected learning progress among school-age children? A growing number of studies address this question, but findings vary depending on context. We conduct a pre-registered systematic review, quality appraisal and meta-analysis of 42 studies across 15 countries to assess the magnitude of the effect of the pandemic on learning. We find a substantial overall learning deficit (Cohen's $d = -0.14$, 95% c.i. $-0.17, -0.10$), which arose early in the pandemic and persists over time. Forgone learning is particularly large among children from low socio-economic backgrounds. It is also larger in math than in reading, and in middle-income countries, relative to high-income countries. There is a lack of evidence on learning progress during the pandemic in low-income countries. Future research should address this evidence gap and avoid the common risks of bias that we identify.

The COVID-19 pandemic has led to one of the largest disruptions to learning in history. To a large extent this is due to school closures, which are estimated to have affected 95 percent of the world's student population.¹ But even when face-to-face teaching resumed, instruction has often been compromised by hybrid teaching, and by children or teachers having to quarantine and miss classes. The effect of limited face-to-face instruction is likely compounded by the pandemic's consequences for children's out-of-school learning environment, as well as their mental and physical health. Lockdowns have restricted children's movement and their ability to play, meet other children, and engage in extra-curricular activities. Children's well-being and family relationships have also suffered due to economic uncertainties and conflicting demands of work, care and learning. These negative consequences can be expected to be most pronounced for children from low socio-economic family backgrounds, exacerbating pre-existing educational inequalities.

It is critical to understand how the COVID-19 pandemic has affected children's learning progress. We use the term 'learning deficit' to encompass both a delay in expected learning progress, as well as a loss of skills and knowledge already gained. The COVID-19 learning deficit is likely to affect children's life chances through their education and labor market prospects. At the societal level, it can have important implications for growth, prosperity, and social cohesion. As policy-makers across the world are seeking to limit further learning deficits and to devise policies to recover learning deficits that have already been incurred, assessing the current state of learning is crucial. A careful assessment of the COVID-19 learning deficit is also necessary to weigh the true costs and benefits of school closures.

A number of narrative reviews have sought to summarize the emerging research on COVID-19 and learning, mostly focusing on learning progress relatively early in the pandemic.^{2,3,4,5,6} Moreover, two reviews harmonized and syn-

thesized existing estimates of the effect of the pandemic on learning progress.^{7,8} In line with the narrative reviews, these two systematic reviews find a statistically significant negative effect of the pandemic on learning. However, this finding is based on a relatively small number of studies (18 and 10 studies respectively). The limited evidence that was available at the time these reviews were conducted also precluded them from meta-analyzing variation in the magnitude of learning deficits over-time and across subjects, different groups of students, or country contexts.

In this paper, we conduct a comprehensive systematic review and meta-analysis of the evidence on COVID-19 learning deficits two and a half years into the pandemic. Our meta-analysis contributes to the existing research in two ways. First, we present a rigorous description and appraisal of the up-to-date body of evidence and its geographic reach and quality. More specifically, we ask (a) What is the state of the evidence, in terms of the available peer-reviewed research and gray-literature, on the effect of the COVID-19 pandemic on learning?, (b) Which countries are represented in the available evidence?, and (c) What is the quality of the existing evidence?

Our second contribution is to harmonize, synthesize and meta-analyze the existing evidence, with special attention to variation across different sub-populations and country contexts. Based on the identified studies, we ask (d) What is the magnitude of the overall effect of the COVID-19 pandemic on learning?, (e) How has the magnitude of the learning deficit evolved since the beginning of the pandemic?, (f) To what extent has the pandemic reinforced inequalities between children from different socio-economic backgrounds? (g) Are there differences in the magnitude of the learning deficit between subject domains (math and reading) and between grade levels (primary and secondary)?, and (h) To what extent does the effect of the pandemic on learning progress vary across countries with different income levels? Below, we report our answers to each of these questions in turn.

The state of the evidence

Our systematic review identified 42 studies on the effect of the COVID-19 pandemic on learning. As shown in Fig. 1,

¹Observatoire Sociologique du Changement (OSC), Sciences Po
²Leverhulme Centre for Demographic Science, University of Oxford
³Department of Social Policy and Intervention, University of Oxford
⁴Nuffield College, University of Oxford
⁵Social Research Institute, University College London
⁶Swedish Institute for Social Research, Stockholm University

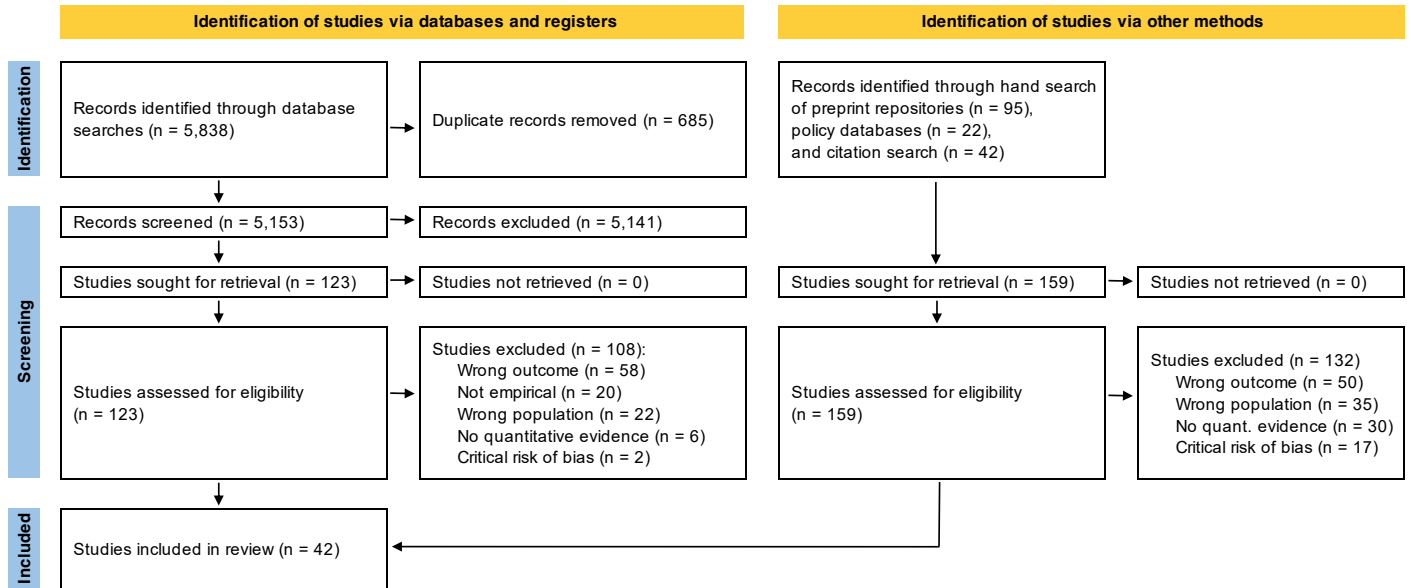


Figure 1: Study identification and selection process (PRISMA flow diagram)

79 the initial literature search resulted in 5,153 hits after re-
 80 moval of duplicates. All studies were double-screened by
 81 the first two authors. Studies had to use a measure of learn-
 82 ing that can be standardized (using Cohen’s d) and base
 83 their estimates on empirical data collected since the onset
 84 of the COVID-19 pandemic (rather than making projections
 85 based on pre-COVID-19 data). The formal database search
 86 process identified 15 eligible studies. We also hand-searched
 87 relevant preprint repositories ($n = 95$) and policy databases
 88 ($n = 22$). Further, to ensure that our study selection was
 89 as up-to-date as possible, we conducted two full forward
 90 and backward citation searches of all included studies on
 91 February 15, 2022, and on August 8, 2022 ($n = 42$). The
 92 citation and preprint hand-searches allowed us to identify
 93 27 additional eligible studies, resulting in a total of 42 stud-
 94 ies. Most of these studies were published after the initial
 95 database search, which illustrates that the body of evidence
 96 continues to expand. Most studies provide multiple esti-
 97 mates of COVID-19 learning deficits, separately for math
 98 and reading and for different school grades. The number of
 99 estimates ($n = 192$) is therefore larger than the number of
 100 included studies ($n = 42$).

101 **The geographic reach of the evidence is limited.** Ta-
 102 ble 1 shows all included studies and estimates of COVID-19
 103 learning deficits (in brackets), grouped by country. 15 coun-
 104 tries are represented: Australia, Belgium, Brazil, Colom-
 105 bia, Denmark, Germany, Italy, Mexico, the Netherlands,
 106 South Africa, Spain, Sweden, Switzerland, the United King-
 107 dom and the United States. About half of the estimates
 108 ($n = 149$) are from the United States, 58 are from the United
 109 Kingdom, a further 70 are from other European countries,
 110 and the remaining 14 estimates are from Australia, Brazil,
 111 Colombia, Mexico, and South Africa. As this list shows,
 112 there is a strong over-representation of studies from high-
 113 income countries, a dearth of studies from middle-income
 114 countries, and no studies from low-income countries. This

skewed representation should be kept in mind when inter-
 115 preting our synthesis of the existing evidence on COVID-19
 116 learning deficits.
 117

The quality of evidence is mixed. We assessed the qual-
 118 ity of the evidence using an adapted version of the Risk Of
 119 Bias In Non-randomized Studies of Interventions (ROBINS-
 120 I) tool.⁵⁰ More specifically, we analyzed the risk of bias of
 121 each estimate from confounding, sample selection, classifi-
 122 cation of treatments, missing data, the measurement of out-
 123 comes, and the selection of reported results. The second au-
 124 thor performed the risk of bias assessments, which were in-
 125 dependently checked by the first and third author. We then
 126 assigned each estimate an overall risk of bias rating (low,
 127 moderate, serious, or critical) based on the estimate and
 128 domain with the highest risk of bias. In line with ROBINS-
 129 I guidance, we excluded all studies rated ‘critical’ ($n=19$)
 130 from our meta-analysis.⁵⁰ Table S2 provides an overview of
 131 these studies as well as the main potential sources of risk of
 132 bias.
 133

Fig. 2A shows the distribution of all studies of COVID-
 134 19 learning deficits according to their risk of bias rating
 135 separately for each domain (top six rows), as well as the
 136 distribution of studies according to their overall risk of bias
 137 rating (bottom row). The overall risk of bias was considered
 138 ‘low’ for 15% of studies, ‘moderate’ for 30% of studies,
 139 ‘serious’ for 25% of studies, and ‘critical’ for 30% of studies.
 140 As shown in Fig. 2A, common sources of potential bias were
 141 confounding, sample selection, and missing data. The likely
 142 consequence of these sources of bias is an underestimation
 143 of COVID-19 learning deficits. Studies rated at risk of con-
 144 founding typically compared only two time points, without
 145 accounting for longer time trends in learning progress. The
 146 main causes of selection bias were the use of convenience
 147 samples and/or insufficient consideration of self-selection by
 148 schools or students. Several studies found evidence of selec-
 149 tion bias, often with students from a low socio-economic
 150

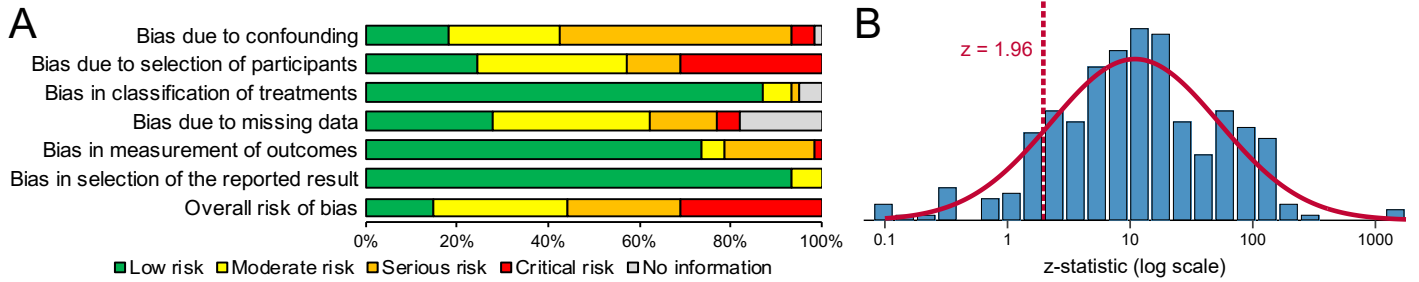


Figure 2: Risk of bias and publication bias. (A) Domain-specific and overall distribution of studies of COVID-19 learning deficits by risk of bias rating using ROBINS-I; includes studies rated to be at critical risk of bias ($n = 19$), which were excluded from the meta-analysis in line with ROBINS-I guidance; (B) z-curve: Distribution of the z-scores of all estimates included in the meta-analysis ($n=291$) to test for publication bias. The dotted line indicates $z = 1.96$ ($p = 0.05$), the conventional threshold for statistical significance. The overlaid curve shows a normal distribution. The absence of a spike in the distribution of the z-scores just above the threshold for statistical significance and the absence of a slump just below it indicate an absence of evidence for publication bias.

Table 1: Studies and estimates by country

| Country | Studies |
|---------------------|---|
| Australia [4] | Gore et al. 2021 [4] ⁹ |
| Belgium [4] | Gambi and De Witte 2021 [2], ¹⁰ Maldonado and De Witte 2021 [2] ¹¹ |
| Brazil [2] | Lichand et al. 2022 [2] ¹² |
| Colombia [2] | Vegas 2022 [2] ¹³ |
| Denmark [7] | Birkelund et al. 2021 [7] ¹⁴ |
| Germany [9] | Depping et al. 2021 [4], ¹⁵ Ludewig et al. 2022 [1], ¹⁶ Schult et al. 2022a [2], ¹⁷ Schult et al. 2022b [2] ¹⁸ |
| Italy [11] | Bazoli et al. 2022 [6], ¹⁹ Borgonovi and Ferrara 2022 [4], ²⁰ Contini et al. 2022 [1] ²¹ |
| Mexico [2] | Hevia et al. 2022 [2] ²² |
| Netherlands [27] | Engzell et al. 2021 [8], ²³ Haelermans 2021 [2], ²⁴ Haelermans et al. 2021 [2], ²⁵ Haelermans et al. 2022 [9], ²⁶ Schuurman et al. 2021 [6] ²⁷ |
| South Africa [2] | Ardington et al. 2021 [2] ²⁸ |
| Spain [3] | Arenas and Gortazar 2022 [3] ²⁹ |
| Sweden [9] | Hallin et al. 2022 [9] ³⁰ |
| Switzerland [2] | Tomasik et al. 2020 [2] ³¹ |
| United Kingdom [58] | Blainey et al. 2021a [12], ³² Blainey et al. 2021b [12], ³³ Blainey et al. 2021c [12], ³⁴ Department for Education 2021a [6], ³⁵ Department for Education 2021b [2], ³⁶ GL Assessment 2021 [4], ³⁷ Rose et al. 2021a [2], ³⁸ Rose et al. 2021b [4] ³⁹ Weidman et al. 2021 [4] ⁴⁰ |
| United States [149] | Domingue et al. 2021a [8], ⁴¹ Domingue et al. 2021b [4], ⁴² Kogan and Lavertu 2021a [1], ⁴³ Kogan and Lavertu 2021b [9], ⁴⁴ Kozakowski et al. 2021 [12], ⁴⁵ Kuhfeld and Lewis 2022 [48], ⁴⁶ Lewis et al. 2021 [12], ⁴⁷ Locke et al. 2021 [14], ⁴⁸ Pier et al. 2021 [25], ⁴⁹ |

Note: Countries and corresponding studies on COVID-19 learning deficits. The number of estimates are shown in brackets, by country (left) and study (right). Full references are indicated by superscript and listed in the bibliography.

background or schools in deprived areas being underrepresented after (as compared to before) the pandemic, but this was not always adjusted for. Some studies also reported a higher amount of missing data post-pandemic, again generally without adjustment, and several studies did not report any information on missing data. For an overview of the risk of bias ratings for each domain of each study see Fig. S2, Table S1 and Table S2.

No evidence of publication bias. Publication bias can occur if authors self-censor to conform to theoretical expectations, or if journals favor statistically significant results. To mitigate this concern, we include not only published papers, but also unpublished working papers and ‘gray literature’, such as policy reports. Moreover, Fig. 2B tests for publication bias by showing the distribution of z-statistics for the effect size estimates of all identified studies. The dotted line indicates $z = 1.96$ ($p = 0.05$), the conventional threshold for statistical significance. The overlaid curve shows a normal distribution. If there was publication bias, we would expect a spike just above the threshold, and a slump just below it. There is no indication of this. Moreover, we do not find a left-skewed distribution of p-values (see p-curve in Fig. S3A), or an association between estimates of learning deficits and their standard errors (see funnel plot in Fig. S3B) that would suggest publication bias. Publication bias does thus not appear to be a major concern.

Results

Having assessed the quality of the existing evidence, we now present the substantive results of our meta-analysis, focusing on the magnitude of COVID-19 learning deficits and on the variation in learning deficits over time, across different groups of students, and across different country contexts.

The COVID-19 pandemic led to substantial learning deficits. Fig. 3 shows the effect sizes that we extracted from each study (averaged across grades and learning subject) as well as the pooled effect size (red diamond). Effects are expressed in standard deviations, using Cohen’s d . Estimates are pooled using inverse variance weights. The pooled effect size across all studies is $d = -0.14$. Under normal circumstances, students generally improve their performance



Figure 3: Forest plot showing individual estimates by study ($n=42$, averaged across subjects and grade levels), and the overall effect size estimate, pooled using inverse variance weights and a random-effects model. Effect sizes are expressed in standard deviations, using Cohen’s d , with 95% confidence intervals, and are sorted by magnitude.

by around 0.4 standard deviations per school year.^{51,52,53} Thus, the overall effect of $d = -0.14$ suggests that students lost out on $0.14/0.4$, or about 35%, of a school year’s worth of learning. On average, the pandemic has led to a substantial learning deficit.

Learning deficits arise early in the pandemic and persist over time. One may expect that children were able to recover learning that was lost early in the pandemic, after teachers and families had time to adjust to the new learning conditions, and structures for online learning and for recovering early learning deficits were set up. However, existing research on teacher strikes in Belgium⁵⁴ and Argentina,⁵⁵ shortened school years in Germany,⁵⁶ and disruptions to education during World War II⁵⁷ suggests that learning deficits are difficult to compensate and tend to persist in the long run.

Fig. 4 plots the magnitude of estimated learning deficits (on the vertical axis) by the date of measurement (on the horizontal axis). The color of the circles reflects the rele-

vant country, the size of the circles indicates the sample size for a given estimate, and the line displays a linear trend. The figure suggests that learning deficits opened up early in the pandemic and have neither closed nor substantially widened since then. This would mean that efforts by children, parents, teachers, and policy-makers to adjust to the changed circumstance have been successful in preventing further learning deficits, but so far have been unable to reverse them. As shown in Fig. S6, the pattern of persistent learning deficits also emerges when we restrict our analysis to the three countries for which we have a relatively large number of estimates at different time points: The United States, the United Kingdom and the Netherlands. However, it is important to note that estimates of learning deficits are based on distinct samples of students and future research should continue to follow the learning progress of cohorts of students affected by the COVID-19 pandemic to reveal how learning deficits of these cohorts develop in different countries.

Socio-economic inequality in education increased during the pandemic. Existing research on the development of learning gaps during summer vacations,^{58,59} disruptions to schooling during the Ebola outbreak in Sierra Leone and Guinea,⁶⁰ and the 2005 earthquake in Pakistan,⁶¹ shows that the suspension of face-to-face teaching can increase educational inequality between children from different socio-economic backgrounds. The effect of the COVID-19 pandemic on learning progress is likely to have been particularly pronounced for children from low socio-economic backgrounds. These children have been more affected by school closures than children from more advantaged backgrounds.⁶² Moreover, they are likely to be disadvantaged with respect to their access and ability to use digital learning technology, the quality of their home learning environment, the learning support they receive from teachers and parents, and their ability to study autonomously.^{63,64,65}

Most studies we identify examine the effect of the pandemic on socio-economic inequality, attesting to the importance of the issue. Because studies use different measures of socio-economic background (e.g., parental income, parental education, free school meal eligibility, neighborhood disadvantage), pooling the estimates is not possible. Instead, we code all estimates according to whether they indicate a positive, negative, or no effect of the pandemic on learning inequality. Fig. 5 displays this information. Estimates that indicate an increase in inequality are shown on the right, those that indicate a decrease on the left, and those that suggest no change in the middle. Squares represent estimates on the effect of the pandemic on inequality in reading performance, and circles represent estimates on the effect of the pandemic on inequality in math performance. The shading represents when in the pandemic educational inequality was measured, differentiating between the first, second and third year of the pandemic. Estimates are also arranged horizontally by grade level. A large majority of estimates indicate an increase in educational inequality between children from different socio-economic backgrounds. This holds for both math and reading, across primary and secondary

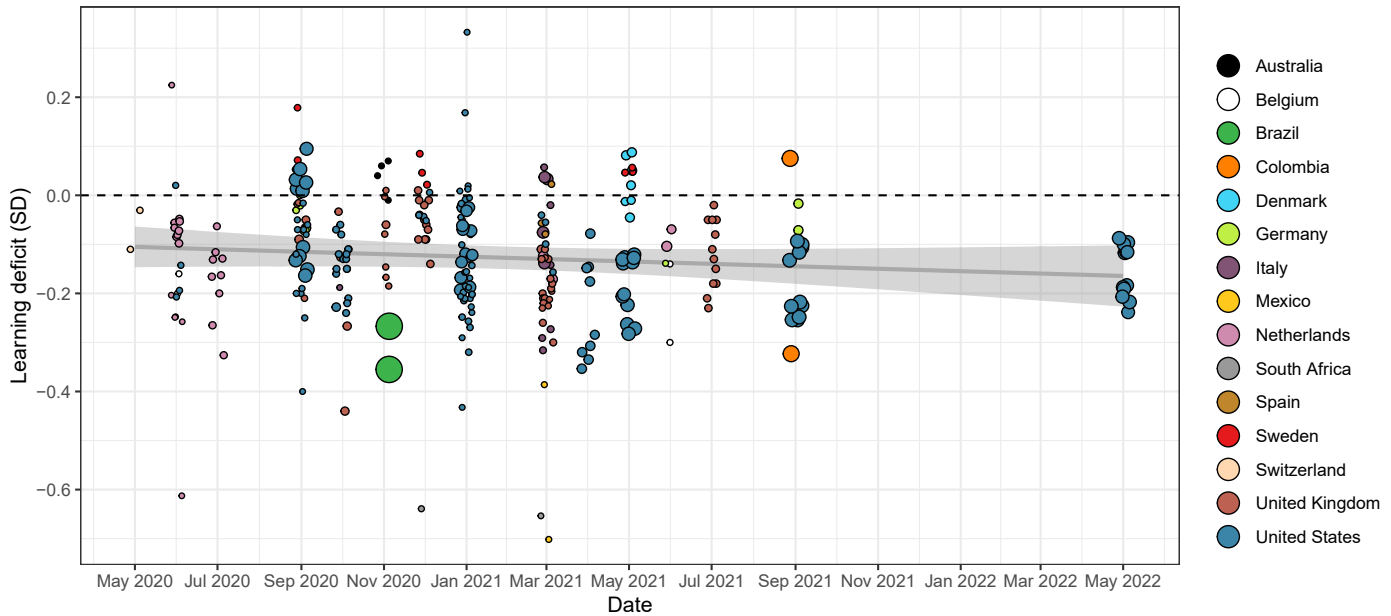


Figure 4: Estimates of COVID-19 learning deficits ($n=291$), by date of measurement. The horizontal axis displays the date on which learning progress was measured. The vertical axis displays estimated learning deficits, expressed in standard deviations using Cohen’s d . The color of the circles reflects the respective country, the size of the circles indicates the sample size for a given estimate, and the line displays a linear trend with a 95% confidence interval.

269 education, at each stage of the pandemic, and independently of how socio-economic background is measured.
270

271 **Learning deficits are larger in math than in reading.** Available research on summer learning deficits,^{58,66}
272 student absenteeism,^{67,68} and extreme weather events,⁶⁹
273 suggests that learning progress in mathematics is more dependent on formal instruction than in reading. This might
274
275

be due to parents being better equipped to help their children with reading, and children advancing their reading skills (but not their math skills) when reading for enjoyment outside of school. Fig. 6A shows that similar to earlier disruptions to learning, the estimated COVID-19 learning deficits are larger for math than for reading (mean difference $\delta = -0.07$, $t = -4.03$, $p = 0.000$). This difference is statistically significant and robust to dropping estimates from individual countries (see Fig. S9).

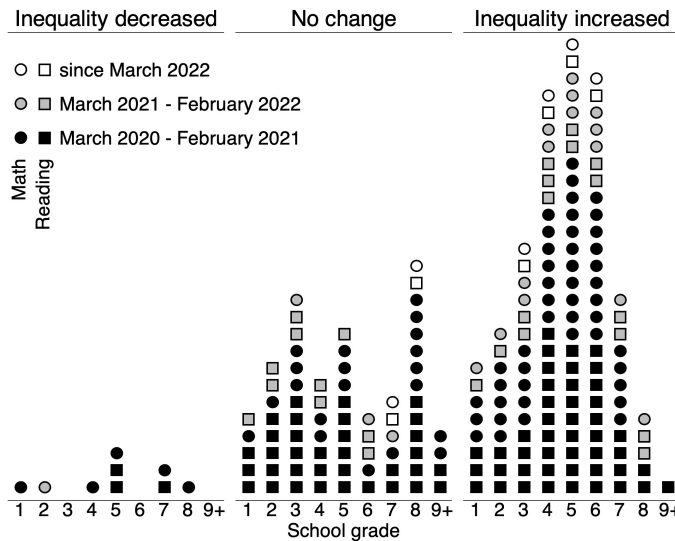


Figure 5: Harvest plot summarizing the evidence on the effect of the pandemic on educational inequality between students from different socio-economic backgrounds. Each circle/square refers to one estimate of over-time change in inequality in math/reading performance ($n=211$). Estimates that find a decrease/no change/increase in inequality are grouped on the left/middle/right. Within these categories, estimates are ordered horizontally by school grade. The shading indicates when in the pandemic a given measure was taken.

285 **No evidence that learning deficits vary across grade levels.** One may expect learning deficits to be smaller for older than for younger children, as older children may be more autonomous in their learning and better able to cope with a sudden change in their learning environment. Fig. 6B shows that, contrary to expectation, we find no evidence of a marked difference in the learning deficits between younger and older students (mean difference $\delta = 0.01$, $t = 0.58$, $p = 0.565$). Note, however, that secondary students were subject to longer school closures in some countries, such as Denmark,¹⁴ based partly on the assumption that they would be better able to learn from home. This may have offset any advantage that older children would otherwise have had in learning from home.

299 **Learning deficits are larger in poorer countries.** Low and middle-income countries were already struggling with a learning crisis before the pandemic. Despite large expansions of the proportion of children in school, children in low and middle-income countries still perform poorly by international standards, and inequality in learning remains high.^{70,71,72} The pandemic is likely to deepen this learning crisis and to undo past progress. Schools in low- and middle-income countries have not only been closed for longer, but

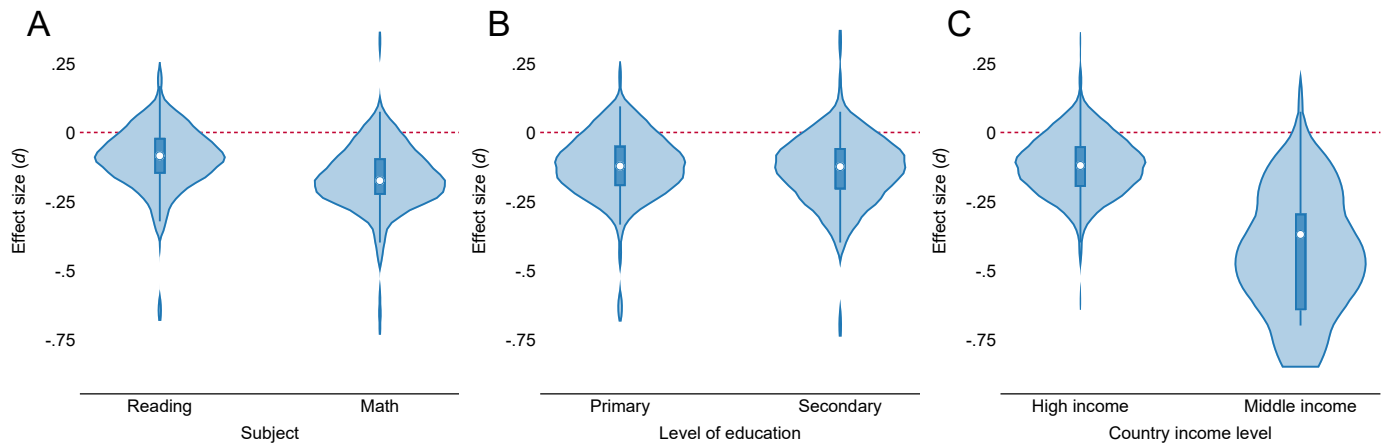


Figure 6: Variation in estimates of COVID-19 learning deficits ($n=291$) across individual- and country-level characteristics: (A) Learning subject (reading vs. math), (B) Level of education (primary vs. secondary), and (C) Country income level (high vs. middle). Each violin plot shows the distribution of COVID-19 learning deficit estimates for the respective subgroup, with the box marking the interquartile range and the white circle denoting the median.

308 have also had fewer resources to facilitate remote learn- 345
 309 ing.^{73,74} Moreover, the economic resources, ICT equipment 346
 310 and ability of children, parents, teachers, and governments 347
 311 to support learning from home are likely to be lower in low- 348
 312 and middle-income countries.⁷⁵ 349

313 As discussed above, most evidence on COVID-19 learn- 350
 314 ing deficits comes from high-income countries. We found 351
 315 no studies on low-income countries that met our inclusion 352
 316 criteria, and evidence from middle-income countries is lim- 353
 317 ited to Brazil, Colombia, Mexico, and South Africa. Fig. 354
 318 6C groups the estimates of COVID-19 learning deficits in 355
 319 these four middle-income countries together (on the right) 356
 320 and compares them to estimates from high-income coun- 357
 321 tries (on the left). The learning deficit is appreciably larger 358
 322 in middle-income countries than in high-income countries 359
 323 (mean difference $\delta = -0.29$, $t = -2.78$, $p = 0.008$). In fact, 360
 324 the three largest estimates of learning deficits in our sample 361
 325 are from middle-income countries^{28,22,12} (see Fig. 3).

326 Discussion

327 Two years into the COVID-19 pandemic, there is still in- 366
 328 sufficient knowledge about its consequences for the learning 367
 329 progress of school-age children. This paper makes two main 368
 330 contributions to better understand the state of the evidence. 369
 331 First, it systematically reviews the existing literature on the 370
 332 effect of the pandemic on learning among school-age children 371
 333 and appraises its geographic reach and quality. Second, it 372
 334 harmonizes, synthesizes and meta-analyzes the existing evi- 373
 335 dence in order to examine the extent to which the pandemic 374
 336 has affected learning, and how this varies across different 375
 337 groups of students and country contexts.

338 We identify a sizable and growing body of evidence on 376
 339 the effects of the pandemic on learning. However, exist- 377
 340 ing studies primarily focus on high-income countries, while 378
 341 there is a dearth of evidence from low- and middle-income 379
 342 countries. This is particularly concerning because the small 380
 343 number of existing studies from middle-income countries 381
 344 suggest that learning deficits have been particularly severe 382

345 in these countries. Learning deficits are likely to be even 346
 347 larger in low-income countries, considering that they already 348
 349 faced a learning crisis before the pandemic, generally im- 349
 350 plemented longer school closures, and were under-resourced 350
 351 and ill-equipped to facilitate remote learning.^{76,75,72,73,74} It 351
 352 is critical that this evidence gap on low- and middle-income 352
 353 countries is addressed swiftly, and that the infrastructure 353
 354 to collect and share data on educational performance in 354
 355 middle- and low-income countries is strengthened. Collect- 355
 356 ing and making available this data is a key prerequisite for 356
 357 fully understanding the effect of the pandemic on learning 357
 358 and related outcomes.⁷⁷ 358

359 About half of the studies that we identify are rated as 359
 360 having a serious or critical risk of bias. Future studies should 360
 361 minimize risk of bias in estimating learning deficits by em- 361
 362 ploying research designs that appropriately account for com- 362
 363 mon sources of bias. These include a lack of accounting for 363
 364 secular time trends, non-representative samples, and imbal- 364
 365 ances between treatment and comparison groups. These 365
 366 potential sources of bias may lead existing studies to under- 366
 367 estimate of learning deficits. 367

368 Our meta-analysis suggests that the COVID-19 pan- 368
 369 demic has led to substantial learning deficits. The pooled 369
 370 effect size of $d = -0.14$, implies that students lost out on 370
 371 about 35%, of a school year's worth of learning. This con- 371
 372 firms initial concerns that the pandemic would cause sub- 372
 373 stantial harm to student learning.^{51,78,79} But our results 373
 374 also suggest that fears of an accumulation of learning deficits 374
 375 as the pandemic continues have not materialized.^{80,81} On 375
 376 average, learning deficits emerged early in the pandemic and 376
 377 have neither closed nor widened. Future research should 377
 378 continue to follow the learning progress of cohorts of stu- 378
 379 dents affected by the COVID-19 pandemic to reveal how 379
 380 learning deficits of these cohorts develop in different coun- 380
 381 tries. 381

382 The persistence of learning deficits two and a half years 382
 into the pandemic highlights the need for well-designed, 382
 well-resourced and decisive policy initiatives to recover

383 learning deficits. Policy-makers, schools, and families will
384 need to identify and realize opportunities to complement
385 and expand on regular school-based learning. Experimental
386 evidence from low- and middle-income countries suggests
387 that even relatively low-tech and low-cost learning inter-
388 ventions can have substantial, positive effects on students’
389 learning progress in the context of remote learning. For
390 example, sending SMS messages with numeracy problems
391 accompanied by a short phone call was found to lead to sub-
392 stantial learning gains in numeracy in Botswana.⁸² Send-
393 ing motivational text messages successfully limited learning
394 losses in math and Portuguese in Brazil.⁸³

395 More evidence is needed to assess the effectiveness
396 of other interventions for limiting or recovering learning
397 deficits. Potential avenues include the use of the often exten-
398 sive summer holidays to offer summer schools and learning
399 camps, extending school days and school weeks, and orga-
400 nizing and scaling up tutoring programs. Further potential
401 lies in developing, improving, advertising and providing ac-
402 cess to learning apps, online learning platforms, or educa-
403 tional TV programs that are free at the point of use. Many
404 countries have already begun investing significant resources
405 to capitalize on some of these opportunities. If these imple-
406 mented interventions prove effective, and if the momentum
407 of existing policy efforts is maintained and expanded, the
408 disruptions to learning during the pandemic may be a win-
409 dow of opportunity to improve and extend the education
410 afforded to children.

411 Most studies that we identify find that learning deficits
412 have been largest for children from disadvantaged socio-
413 economic backgrounds. This holds across different time
414 points during the pandemic, countries, grade levels, and
415 learning subjects, and independently of how socio-economic
416 background is measured. This suggests that the pandemic
417 has exacerbated educational inequalities between children
418 from different socio-economic backgrounds, which were al-
419 ready large before the pandemic.^{84,85} Policy initiatives to
420 compensate learning deficits need to prioritize support for
421 children from low socio-economic backgrounds in order to
422 allow them to recover the learning they lost during the pan-
423 demic.

424 There is a need for future research to assess how the
425 COVID-19 pandemic has affected gender inequality in edu-
426 cation. To date, there is very little evidence on this issue,
427 and the large majority of the studies that we identified do
428 not empirically examine learning deficits separately by gen-
429 der.

430 Comparing estimates of learning deficits across subjects,
431 we find that learning deficits tend to be larger in math than
432 in reading. As noted above, this may be due to the fact
433 that parents and children have been in a better position to
434 compensate school-based learning in reading by reading at
435 home. Accordingly, there are grounds for policy initiatives
436 to prioritize the compensation of learning deficits in math
437 and other science subjects.

438 Our analysis provides important evidence of how the
439 COVID-19 learning deficit has varied between different
440 groups of students and across country contexts. Given the
441 limited reach of the existing evidence, we do not seek to

identify the causal role of specific factors. A fruitful av- 442
enue for future research will be to use quasi-experimental 443
designs to reveal how specific factors can account for indi- 444
vidual and society-level variation in the extent of COVID- 445
19 learning deficits. The considerable variation in learning 446
deficits across sub-populations and country contexts that we 447
find highlights the need to better understand this variation, 448
and identify mechanisms that can guide policy measures for 449
limiting and counteracting learning deficits. 450

451 Methods

Eligibility criteria. We consider all types of primary 452
research, including peer-reviewed publications, preprints, 453
working papers, and reports for inclusion. To be eligible 454
for inclusion, studies have to measure learning progress us- 455
ing test scores that can be standardized across studies using 456
Cohen’s *d*. Moreover, studies have to be in English, Danish, 457
Dutch, French, German, Norwegian, Spanish or Swedish. 458

Search strategy and study identification. We iden- 459
tify eligible studies using the following steps. First, we 460
developed a Boolean search string defining our population 461
(school-aged children), exposure (the COVID-19 pandemic), 462
and outcomes of interest (e.g., math and reading). The full 463
search string can be found in Section 1 of the Supplementary 464
Information. We used this string to search the following aca- 465
demic databases: Coronavirus Research Database, Educa- 466
tion Database, ERIC, International Bibliography of the So- 467
cial Sciences (IBSS), Politics Collection (PAIS index, policy 468
file index, political science database, and worldwide political 469
science abstracts), Social Science Database, Sociology Col- 470
lection (applied social science index [ASSIA] and abstracts, 471
sociological abstracts, and sociology database), CINAHL, 472
and Web of Science. Our initial search was conducted on 473
April 27, 2021. Second, we hand-searched multiple preprint, 474
working paper, and policy document repositories (SSRN, 475
MPRA, IZA, NBER, OSF Preprints, PsyArXiv, SocArXiv, 476
and EdArXiv) and relevant policy websites, including, but 477
not limited to, the websites of the Organisation for Eco- 478
nomic Co-operation and Development, the United Nations, 479
the World Bank, and the Education Endowment Founda- 480
tion. Third, we periodically posted our protocol via Twitter 481
in order to crowdsource additional relevant studies not iden- 482
tified through the search. Last, to ensure that our analysis 483
is comprehensive in terms of recent and relevant research, 484
on February 14, 2022, and on August 8, 2022, we conducted 485
two comprehensive forward and backward citation searches 486
of all eligible studies identified in the above steps. 487

Data extraction. From the studies that meet our inclu- 488
sion criteria we extract all estimates of the effect of the pan- 489
demic on learning progress, separately for math and reading 490
and for different school grades. We also extract the corre- 491
sponding sample size, standard error, date(s) of measure- 492
ment, author name(s), and country. Last, we record whether 493
studies differentiate between children’s socio-economic back- 494
ground, which measure is used to this end, and whether 495
studies find an increase, decrease or no change in learning 496
inequality. We contacted study authors, if any of the above 497
information was missing in the study. Data extraction was 498

performed by the first author and validated independently by the second author, with discrepancies resolved through discussion and by conferring with the third author.

Measurement and standardization. We standardize all estimates of the effect of the pandemic on learning using Cohen’s d , which expresses effect sizes in terms of standard deviations. Cohen’s d is calculated as the difference in the mean learning gain in a given subject (math or reading) over two comparable periods before and after the onset of the pandemic, divided by the pooled standard deviation of learning progress in this subject:

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s},$$

where

$$s = \sqrt{\frac{(s_1^2 + s_2^2)}{2}}.$$

Effect sizes expressed as β coefficients are converted to Cohen’s d :

$$d = \frac{\beta}{se} \times \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}.$$

Subject. We use a binary indicator for whether the study outcome is math or reading. One study does not differentiate the outcome but includes a composite of math and reading scores.³¹

Level of education. We distinguish between primary and secondary education. We first consulted the original studies for this information. In cases where it was not stated in a given study, students’ age was used in conjunction with information about education systems from external sources to determine the level of education.⁸⁶

Country income level. We follow the World Bank’s classification of countries into four income groups: low, lower-middle, upper-middle, and high-income. Four countries in our sample place are in the upper-middle group: Brazil, Colombia, Mexico and South Africa. Remaining countries are high-income.

Data synthesis. We synthesize our data using three synthesis techniques. First, we generate a forest plot, based on all available estimates of the effect of the pandemic on learning. We pool estimates using a random-effects REML model and inverse variance weights to calculate an overall effect size (see Fig. 3).⁸⁷ Second, we code all estimates of the effect of the pandemic on educational inequality between children from different socio-economic backgrounds, according to whether they indicate a positive, negative, or no effect. We visualize the resulting distribution using a harvest plot (see Fig. 5).⁸⁸ Third, given that the limited amount of available evidence precludes multivariate or causal analyses, we examine the bivariate association between COVID-19 learning deficits and the months in which learning was measured (see Fig. 4) learning subject, grade, and countries’ income level, using a series of violin plots (see Fig. 6). The reported estimates, confidence intervals and statistical significance tests of these bivariate associations are based on common-effects models with standard errors clustered by study, and two-sided tests.

Pre-registration. We prospectively registered a protocol of our systematic review and meta-analysis in the International Prospective Register of Systematic Reviews (CRD42021249944) on 19 April 2021.

Acknowledgements. B.B. gratefully acknowledges funding from the Observatoire Sociologique du Changement (OSC), Sciences Po. A.B.M. gratefully acknowledges funding from the Carlsberg Foundation. P.E. gratefully acknowledges funding from the Leverhulme Centre for Demographic Science, The Leverhulme Trust, and the Swedish council for working life and social research (grant no. 2016-07099).

References

- United Nations. The impact of COVID-19 on children. UN Policy Briefs (2020).
- Donnelly, R. & Patrinos, H. A. Learning loss during covid-19: An early systematic review. *Prospects* 1–9 (2021).
- Hammerstein, S., König, C., Dreisörner, T. & Frey, A. Effects of COVID-19-related school closures on student achievement: A systematic review. *Frontiers in Psychology* 4020 (2021).
- Panagouli, E. *et al.* School performance among children and adolescents during COVID-19 pandemic: A systematic review. *Children* **8**, 1134 (2021).
- Patrinos, H. A., Vegas, E. & Carter-Rau, R. An analysis of COVID-19 student learning loss. World Bank, Washington, DC (2022).
- Zierer, K. Effects of pandemic-related school closures on pupils’ performance and learning in selected countries: A rapid review. *Education Sciences* **11**, 252 (2021).
- König, C. & Frey, A. The impact of COVID-19-related school closures on student achievement: A meta-analysis. *Educational Measurement: Issues and Practice* **41**, 16–22 (2022).
- Storey, N. & Zhang, Q. A meta-analysis of COVID learning loss. EdArXiv (2021).
- Gore, J., Fray, L., Miller, A., Harris, J. & Taggart, W. The impact of COVID-19 on student learning in New South Wales primary schools: an empirical study. *The Australian Educational Researcher* **48**, 605–637 (2021).
- Gambi, L. & De Witte, K. The resiliency of school outcomes after the COVID-19 pandemic: Standardised test scores and inequality one year after long term school closures. *FEB Research Report Department of Economics* (2021).
- Maldonado, J. E. & De Witte, K. The effect of school closures on standardised student test outcomes. *British Educational Research Journal* **48**, 49–94 (2021).
- Lichand, G., Doria, C. A., Leal-Neto, O. & Fernandes, J. P. C. The impacts of remote learning in secondary education during the pandemic in Brazil. *Nature Human Behaviour* 1–8 (2022).

- 597 ¹³ Vegas, E. COVID-19's impact on learning losses and
598 learning inequality in Colombia. Center for Universal Ed-
599 ucation at Brookings (2022).
- 600 ¹⁴ Birkelund, J. F. & Karlson, K. B. No evidence of a major
601 learning slide 14 months into the COVID-19 pandemic in
602 Denmark. SocArXiv (2021).
- 603 ¹⁵ Depping, D., Lücken, M., Musekamp, F. & Thonke,
604 F. Kompetenzstände Hamburger Schüler*innen vor
605 und während der Corona-Pandemie. In Fickermann,
606 D. & Edelstein, B. (eds.) *Schule während der Corona-
607 Pandemie. Neue Ergebnisse und Überblick über ein dy-
608 namisches Forschungsfeld*, 51–79 (Münster & New York:
609 Waxmann, 2021).
- 610 ¹⁶ Ludewig, U. *et al.* Die COVID-19 Pandemie und
611 Lesekompetenz von Viertklässler*innen: Ergebnisse der
612 IFS-Schulpanelstudie 2016-2021. Institut für Schul-
613 entwicklungsforchung, Universität Dortmund (2022).
- 614 ¹⁷ Schult, J., Mahler, N., Fauth, B. & Lindner, M. A.
615 Did students learn less during the COVID-19 pandemic?:
616 Reading and mathematics competencies before and after
617 the first pandemic wave. *School Effectiveness and School
618 Improvement* 1–20 (2022).
- 619 ¹⁸ Schult, J., Mahler, N., Fauth, B. & Lindner, M. A.
620 Long-term consequences of repeated school closures dur-
621 ing the COVID-19 pandemic for reading and mathemat-
622 ics competencies. *Frontiers in Education* **13** (2022). URL
623 <https://doi.org/10.3389/feduc.2022.867316>.
- 624 ¹⁹ Bazoli, N., Marzadro, S., Schizzerotto, A. & Vergolini,
625 L. Learning loss and students' social origins during the
626 COVID-19 pandemic in Italy. *FBK-IRVAPP Working Pa-
627 pers* **3** (2022).
- 628 ²⁰ Borgonovi, F. & Ferrara, A. The effects of COVID-19 on
629 inequalities in educational achievement in Italy. Available
630 at SSRN 4171968 (2022).
- 631 ²¹ Contini, D., Di Tommaso, M. L., Muratori, C., Piazza-
632 lunga, D. & Schiavon, L. Who lost the most?: Mathe-
633 matics achievement during the COVID-19 pandemic. *The
634 BE Journal of Economic Analysis & Policy* **22**, 399–408
635 (2022).
- 636 ²² Hevia, F. J., Vergara-Lope, S., Velásquez-Durán, A. &
637 Calderón, D. Estimation of the fundamental learning loss
638 and learning poverty related to COVID-19 pandemic in
639 Mexico. *International Journal of Educational Develop-
640 ment* **88**, 102515 (2022).
- 641 ²³ Engzell, P., Frey, A. & Verhagen, M. D. Learning loss due
642 to school closures during the COVID-19 pandemic. *Pro-
643 ceedings of the National Academy of Sciences* **118** (2021).
- 644 ²⁴ Haelermans, C. Learning growth and inequality in pri-
645 mary education: Policy lessons from the COVID-19 crisis.
646 The European Liberal Forum (ELF)-FORES (2021).
- 647 ²⁵ Haelermans, C. *et al.* A full year COVID-19 crisis with
648 interrupted learning and two school closures: The effects
649 on learning growth and inequality in primary education.
650 Maastricht University, Research Centre for Education and
651 the Labour Market (ROA) (2021).
- 652 ²⁶ Haelermans, C. *et al.* Sharp increase in inequality in ed-
653 ucation in times of the COVID-19-pandemic. *PLoS One*
654 **17**, e0261114 (2022).
- 655 ²⁷ Schuurman, T. M., Henrichs, L. F., Schuurman, N. K.,
656 Polderdijk, S. & Hornstra, L. Learning loss in vulnera-
657 ble student populations after the first COVID-19 school
658 closure in the Netherlands. *Scandinavian Journal of Ed-
659 ucational Research* 1–18 (2021).
- 660 ²⁸ Ardington, C., Wills, G. & Kotze, J. COVID-19 learning
661 losses: Early grade reading in South Africa. *International
662 Journal of Educational Development* **86**, 102480 (2021).
- 663 ²⁹ Arenas, A. & Gortazar, L. Learning loss one year after
664 school closures. *Esade Working Paper* (2022).
- 665 ³⁰ Hallin, A. E., Danielsson, H., Nordström, T. & Fälth, L.
666 No learning loss in Sweden during the pandemic evidence
667 from primary school reading assessments. *International
668 Journal of Educational Research* **114**, 102011 (2022).
- 669 ³¹ Tomasik, M. J., Helbling, L. A. & Moser, U. Educa-
670 tional gains of in-person vs. distance learning in primary
671 and secondary schools: A natural experiment during the
672 COVID-19 pandemic school closures in Switzerland. *In-
673 ternational Journal of Psychology* **56**, 566–576 (2021).
- 674 ³² Blainey, K. & Hannay, T. The impact of school closures
675 on autumn 2020 attainment. RS Assessment from Hodder
676 Education (2021).
- 677 ³³ Blainey, K. & Hannay, T. The impact of school closures
678 on spring 2021 attainment. RS Assessment from Hodder
679 Education (2021).
- 680 ³⁴ Blainey, K. & Hannay, T. The effects of educational dis-
681 ruption on primary school attainment in summer 2021.
682 RS Assessment from Hodder Education (2021).
- 683 ³⁵ Department for Education. Understanding progress in
684 the 2020/21 academic year: Complete findings from the
685 autumn term. London: Department for Education (2021).
- 686 ³⁶ Department for Education. Understanding progress in the
687 2020/21 academic year: Initial findings from the spring
688 term. London: Department for Education (2021).
- 689 ³⁷ GL Assessment. Impact of COVID-19 on attainment: ini-
690 tial analysis. Brentford: GL Assessment (2021).
- 691 ³⁸ Rose, S. *et al.* Impact of school closures and subsequent
692 support strategies on attainment and socio-emotional
693 wellbeing in key stage 1: Interim paper 1. London: Na-
694 tional Foundation for Educational Research (NFER), Ed-
695 ucation Endowment Foundation (EEF).

- 696 39 Rose, S. *et al.* Impact of school closures and subsequent
697 support strategies on attainment and socio-emotional
698 wellbeing in key stage 1: Interim paper 2. London: Na-
699 tional Foundation for Educational Research (NFER), Ed-
700 ucation Endowment Foundation (EEF).
- 701 40 Weidmann, B. *et al.* COVID-19 disruptions: Attainment
702 gaps and primary school responses. *Education Endow-*
703 *ment Foundation: London, UK* (2021).
- 704 41 Domingue, B. W., Hough, H. J., Lang, D. & Yeatman,
705 J. Changing patterns of growth in oral reading fluency
706 during the COVID-19 pandemic. PACE Working Paper,
707 Policy Analysis for California Education (2021).
- 708 42 Domingue, B. *et al.* The effect of COVID on oral reading
709 fluency during the 2020-2021 academic year. EdArXiv
710 (2021).
- 711 43 Kogan, V. & Lavertu, S. The COVID-19 pandemic and
712 student achievement on Ohio's third-grade English lan-
713 guage arts assessment. Ohio State University (2021).
- 714 44 Kogan, V. & Lavertu, S. How the COVID-19 pandemic
715 affected student learning in Ohio: Analysis of spring 2021
716 Ohio state tests. Ohio State University (2021).
- 717 45 Kozakowski, W., Gill, B., Lavalley, P., Burnett, A. &
718 Ladinsky, J. Changes in academic achievement in Pitts-
719 burgh public schools during remote instruction in the
720 COVID-19 pandemic. Institute of Education Sciences
721 (IES), U.S. Department of Education (2020).
- 722 46 Kuhfeld, M. & Lewis, K. Student achievement in
723 2021–2022: Cause for hope and continued urgency.
724 NWEA (2022).
- 725 47 Lewis, K., Kuhfeld, M., Ruzek, E. & McEachin, A. Learn-
726 ing during COVID-19: Reading and math achievement in
727 the 2020-21 school year. NWEA (2021).
- 728 48 Locke, V. N., Patarapichayatham, C. & Lewis, S. Learn-
729 ing loss in reading and math in US schools due to the
730 COVID-19 pandemic. Istation (2021).
- 731 49 Pier, L., Christian, M., Tymeson, H. & Meyer, R. H.
732 COVID-19 impacts on student learning: Evidence from
733 interim assessments in California. PACE Working Paper,
734 Policy Analysis for California Education (2021).
- 735 50 Sterne, J. A. *et al.* ROBINS-I: A tool for assessing risk
736 of bias in non-randomised studies of interventions. *BMJ*
737 **355** (2016).
- 738 51 Azevedo, J. P., Hasan, A., Goldemberg, D., Iqbal, S. A. &
739 Geven, K. Simulating the potential impacts of COVID-19
740 school closures on schooling and learning outcomes: A set
741 of global estimates. *World Bank Policy Research Working*
742 *Paper* (2020).
- 743 52 Bloom, H. S., Hill, C. J., Black, A. R. & Lipsey,
744 M. W. Performance trajectories and performance gaps
745 as achievement effect-size benchmarks for educational in-
746 terventions. *Journal of Research on Educational Effec-*
747 *tiveness* **1**, 289–328 (2008).
- 53 Hill, C. J., Bloom, H. S., Black, A. R. & Lipsey,
748 M. W. Empirical benchmarks for interpreting effect sizes
749 in research. *Child Development Perspectives* **2**, 172–177
750 (2008).
751
- 54 Belot, M. & Webbink, D. Do teacher strikes harm ed-
752 ucational attainment of students? *Labour* **24**, 391–406
753 (2010).
754
- 55 Jaume, D. & Willén, A. The long-run effects of teacher
755 strikes: Evidence from Argentina. *Journal of Labor Eco-*
756 *nomics* **37**, 1097–1139 (2019).
757
- 56 Cygan-Rehm, K. Are there no wage returns to compul-
758 sory schooling in Germany?: A reassessment. *Journal of*
759 *Applied Econometrics* **37**, 218–223 (2022).
760
- 57 Ichino, A. & Winter-Ebmer, R. The long-run educational
761 cost of World War II. *Journal of Labor Economics* **22**,
762 57–87 (2004).
763
- 58 Cooper, H., Nye, B., Charlton, K., Lindsay, J. &
764 Greathouse, S. The effects of summer vacation on achieve-
765 ment test scores: A narrative and meta-analytic review.
766 *Review of Educational Research* **66**, 227–268 (1996).
767
- 59 Allington, R. L. *et al.* Addressing summer reading setback
768 among economically disadvantaged elementary students.
769 *Reading Psychology* **31**, 411–427 (2010).
770
- 60 Smith, W. C. Consequences of school closure on access to
771 education: Lessons from the 2013–2016 Ebola pandemic.
772 *International Review of Education* **67**, 53–78 (2021).
773
- 61 Andrabi, T., Daniels, B. & Das, J. Human capital ac-
774 cumulation and disasters: Evidence from the Pakistan
775 earthquake of 2005. *Journal of Human Resources* 0520–
776 10887R1 (2021).
777
- 62 Parolin, Z. & Lee, E. K. Large socio-economic, geographic
778 and demographic disparities exist in exposure to school
779 closures. *Nature Human Behaviour* **5**, 522–528 (2021).
780
- 63 Goudeau, S., Sanrey, C., Stanczak, A., Manstead, A. &
781 Darnon, C. Why lockdown and distance learning during
782 the COVID-19 pandemic are likely to increase the social
783 class achievement gap. *Nature Human Behaviour* **5**, 1273–
784 1281 (2021).
785
- 64 Bailey, D. H., Duncan, G. J., Murnane, R. J. & Au Ye-
786 ung, N. Achievement gaps in the wake of COVID-19.
787 *Educational Researcher* **50**, 266–275 (2021).
788
- 65 van de Werfhorst, H. G. Inequality in learning is a major
789 concern after school closures. *Proceedings of the National*
790 *Academy of Sciences* **118** (2021).
791
- 66 Alexander, K. L., Entwisle, D. R. & Olson, L. S. Schools,
792 achievement, and inequality: A seasonal perspective. *Ed-*
793 *ucational Evaluation and Policy Analysis* **23**, 171–191
794 (2001).
795
- 67 Aucejo, E. M. & Romano, T. F. Assessing the effect
796 of school days and absences on test score performance.
797 *Economics of Education Review* **55**, 70–87 (2016).
798

- 799 ⁶⁸ Gottfried, M. A. The detrimental effects of missing school: Evidence from urban siblings. *American Journal of Education* **117**, 147–182 (2011).
800
801
- 802 ⁶⁹ Goodman, J. Flaking out: Student absences and snow days as disruptions of instructional time. National Bureau of Economic Research (2014).
803
804
- 805 ⁷⁰ Angrist, N., Djankov, S., Goldberg, P. K. & Patrinos, H. A. Measuring human capital using global learning data. *Nature* **592**, 403–408 (2021).
806
807
- 808 ⁷¹ Torche, F. Educational mobility in the developing world. In Iversen, V., Krishna, A. & Sen, K. (eds.) *Social Mobility in Developing Countries: Concepts, Methods, and Determinants*, 139–171 (Oxford University Press, 2021).
809
810
811
- 812 ⁷² World Bank. *World development report 2018: Learning to realize education's promise* (The World Bank, 2018).
813
- 814 ⁷³ United Nations. Policy brief: Education during COVID-19 and beyond. United Nations (2020).
815
- 816 ⁷⁴ UNESCO. One year into COVID-19 education disruption: Where do we stand? <https://en.unesco.org/news/one-year-covid-19-education-disruption-where-do-we-stand> (2021). Accessed: 2022-09-01.
817
818
819
- 820 ⁷⁵ Azevedo, J. P., Hasan, A., Goldemberg, D., Geven, K. & Iqbal, S. A. Simulating the potential impacts of COVID-19 school closures on schooling and learning outcomes: A set of global estimates. *The World Bank Research Observer* **36**, 1–40 (2021).
821
822
823
824
- 825 ⁷⁶ Angrist, N. *et al.* Building back better to avert a learning catastrophe: Estimating learning loss from covid-19 school shutdowns in africa and facilitating short-term and long-term learning recovery. *International Journal of Educational Development* **84**, 102397 (2021).
826
827
828
829
- 830 ⁷⁷ Conley, D. & Johnson, T. Opinion: Past is future for the era of COVID-19 research in the social sciences. *Proceedings of the National Academy of Sciences* **118** (2021).
831
832
- 833 ⁷⁸ Major, L. E., Eyles, A., Machin, S. *et al.* Learning loss since lockdown: variation across the home nations. Centre for Economic Performance, London School of Economics and Political Science (2021).
834
835
836
- 837 ⁷⁹ Di Pietro, G., Biagi, F., Costa, P., Karpinski, Z. & Mazza, J. The likely impact of COVID-19 on education: Reflections based on the existing literature and recent international datasets. Publications Office of the European Union (2020).
838
839
840
841
- 842 ⁸⁰ Fuchs-Schündeln, N., Krueger, D., Ludwig, A. & Popova, I. The long-term distributional and welfare effects of COVID-19 school closures. National Bureau of Economic Research (2020).
843
844
845
- 846 ⁸¹ Kaffenberger, M. Modelling the long-run learning impact of the COVID-19 learning shock: Actions to (more than) mitigate loss. *International Journal of Educational Development* **81**, 102326 (2021).
847
848
849
- ⁸² Angrist, N., Bergman, P. & Matsheng, M. Experimental evidence on learning using low-tech when school is out. *Nature Human Behaviour* **6**, 941–950 (2022).
850
851
852
- ⁸³ Lichand, G., Christen, J. & van Egeraat, E. Do behavioral nudges work under remote learning? evidence from brazil during the pandemic. University of Zurich, Department of Economics, Working Paper (2022).
853
854
855
856
- ⁸⁴ Attewell, P. & Newman, K. S. *Growing gaps: Educational inequality around the world* (Oxford University Press, 2010).
857
858
859
- ⁸⁵ Betthäuser, B. A., Kaiser, C. & Trinh, N. A. Regional variation in inequality of educational opportunity across europe. *Socius* **7**, 23780231211019890 (2021).
860
861
862
- ⁸⁶ Eurydice. Eurybase: the information database on education systems in Europe (2021).
863
864
- ⁸⁷ Borenstein, M., Hedges, L. V., Higgins, J. P. & Rothstein, H. R. A basic introduction to fixed-effect and random-effects models for meta-analysis. *Research Synthesis Methods* **1**, 97–111 (2010).
865
866
867
868
- ⁸⁸ Ogilvie, D. *et al.* The harvest plot: A method for synthesising evidence about the differential effects of interventions. *BMC Medical Research Methodology* **8**, 1–7 (2008).
869
870
871