

Research article

The impact of the COVID-19 pandemic on primary school students' mathematical reasoning skills: a mediation analysis

Kerem Coskun^{1,*}, Cihan Kara¹

¹ Education Faculty, Artvin Coruh University, Seyitler, Turkey

* Correspondence: keremcoskun@artvin.edu.tr

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Abstract

The present research aimed to reveal how the COVID-19 pandemic influenced the mathematical reasoning of primary school students through mediation analysis. It was designed as *ex post facto* research. The research sample consisted of two cohorts. Cohort 1 included 415 primary school children who received face-to-face instruction by attending school for six months until COVID-19 emerged. Cohort 2 included 964 children who were taught curricular skills through distance education due to COVID-19 and school closures. In total, 1,379 primary school children were recruited into the research sample. Data were collected through a mathematical reasoning test by sending items from the instrument via Google Docs. The data were analysed with mediation analysis. Results demonstrated that the school closures due to the COVID-19 pandemic negatively influenced mathematical reasoning skills. Findings are discussed in the light of human interaction and Cattell's intelligence theory.

Keywords COVID-19; mathematical reasoning; socio-economic status; primary school students

Introduction

When COVID-19 was declared a pandemic by the World Health Organization on 11 March 2020, 107 governments enforced nationwide school closures in order to slow down the transmission of the virus, reduce burdens on healthcare systems and protect high-risk populations from the disease (Armitage and Nellums, 2020; Viner et al., 2020).

This was because social contact at schools is twice as high as contact during the holidays and weekends for an ordinary school child (Eames et al., 2010, 2011), and children are less capable of applying hygiene rules and have higher viral shedding than adults (Abdollahi et al., 2020). Closing down schools to impede virus spread during the first phase of the pandemic seemed plausible. However, the cost of school closure emerged gradually.

Lockdown restrictions and home confinement impaired children's well-being and increased psychological harm. School closures and lockdown restrictions destroyed social interaction with peers and elderly relatives. As a result, children experienced isolation, loneliness, fear of infection and stress (Brooks et al., 2020). In other words, lockdown restrictions and school closures meant losing direct contact with schoolmates, teachers, grandparents and other relatives, which led children to experience negative moods.

School closure caused by the COVID-19 pandemic is the most remarkable disruption to education in history because of the fact that 1.6 billion students stayed at home and received curricular instruction through screens (UN, 2020). As a result of school closures, learning settings, student–teacher interactions and methods of instruction completely changed. Changes in student–teacher interactions and learning setting, in turn, led students to receive less guidance, direction and support from their teachers. Lack of robust student–teacher interaction brought self-regulated learning skills to the fore because these helped students to learn the curricular content distributed on online learning portals.

Higher-achieving children were capable of regulating their learning on their own initiative during school closures, whereas lower-achieving children lacked self-regulated learning skills and were more dependent on support, direction and guidance from their teachers. Consequently, school closures disrupted the learning of lower-achieving children more, and widened the existing gap between the two groups (Grewenig et al., 2021). School closures caused direct interaction and contact between teacher and student to disappear (Andrew et al., 2020). As a result, lack of self-regulation skills and absence of direct student–teacher interaction allowed students to be influenced easily by distractions in the home learning environment. This influence, in turn, led to them spending less time on learning and more time on detrimental activities, such as watching television, and more interaction with social media and video games (Grewenig et al., 2021).

In addition to the problem of differences in possession of self-regulated learning skills among the students, another problem with the online learning environment was related to adaptation. Schools and teachers experienced difficulty in adapting to online classroom environments (Grewenig et al., 2021; Kuhfeld et al., 2020). The online learning environment dramatically changed student–teacher interactions, and this dramatic change, in turn, was associated with a decrease in student achievement and increased dispersion of academic achievement (Chetty et al., 2020; The DELVE Initiative, 2020).

The shift from classroom curricular activities to distance learning activities made parental education more important, because parents were expected to undertake half of the teaching responsibility when schools were closed (Thomas and Rogers, 2020). Children whose parents hold a university degree tend to spend more time on learning at home. However, children whose parents do not have any university degree spend more time on detrimental activities. As a consequence, the school closure exacerbated the existing skills and knowledge gap associated with parental and familial background (Blaskó and Schnepf, 2020; Di Pietro et al., 2020; Haack and Lefebvre, 2020; Engzell et al., 2021; Grewenig et al., 2021; Maldonado and De Witte, 2020; UN, 2020). Additionally, the home learning environment gained more importance compared to the classroom environment because of the fact that the place of learning moved from classrooms to homes. Lack of digital skills, poor access to the internet, connectivity for distance

learning and attentional hygiene in the homes substantially deteriorated the problems related to school closure, owing to the fact that the facilities and characteristics of the home learning environment vary remarkably based on socio-economic status. As a result, parents' low education level and insufficient digital skills deprived vulnerable children of distance education (Blaskó and Schnepf, 2020; Di Pietro et al., 2020).

When the damage due to school closures is more specifically addressed, the most serious damage was learning loss. Learning loss refers to the decline in knowledge and skill gain. It can be detected when knowledge and skill progress does not appear to occur at the same pace through comparisons of two successive years (Pier et al., 2021). Mathematical reasoning is one of the skills where learning loss may occur, because mathematical reasoning comprises basic learning and is a learning outcome that can be fostered by schooling and student–teacher interaction. Thus, it is sensible to think that mathematical reasoning will be affected in the absence of student–teacher interaction and schooling. Mathematical reasoning consists of abilities to establish mathematical surmise, develop hypotheses and evaluate, choose and use different kinds of representations (Melhuish et al., 2020).

Mathematical reasoning helps primary school children's mathematical understanding, fluency in mathematics and robust problem-solving skills to flourish. In other words, children use mathematical reasoning skills to reach a conclusion in a problem case. Mathematical reasoning can play an essential role when children try to transfer mathematical knowledge from one context to another (ACARA, 2013). Possession of proficient mathematical reasoning requires comparison of units, justifying conclusions with data and using mathematical operations to find patterns. Hence, reasoning goes beyond just giving reasons.

Mathematical reasoning requires the ability to develop hypotheses, build and assess mathematical arguments, discover patterns and relationships, and select and use strategies to solve a problem (Kramarski and Mevarech, 2003; Stein et al., 1996). As a consequence, mathematical reasoning consists of a very wide range of skills, and school curricula have allocated remarkable space and time to teaching it.

Several studies were conducted to explore learning loss stemming from school closures. Maldonado and De Witte (2020) assessed learning loss among primary school children in social science, mathematics and Dutch, and they detected loss after school closure for nine weeks. Engzell et al. (2021) measured the impact of school closures that lasted eight weeks in Dutch primary school children aged from 7 to 11 years, and they observed that learning loss occurred in maths, reading and spelling. Tomasik et al. (2021) found significant declines in primary school children's maths skills after eight weeks of school closure in Switzerland. Similarly, Kuhfeld et al. (2020) observed a remarkable decrease in primary school children's maths scores after unspecified school closures. Gore et al. (2021) reported that there was an insignificant fall in maths scores of primary school children after eight- to ten-week school closure in New South Wales, Australia. Asakawa and Ohtake (2021) found significant declines in primary school children's maths scores during temporary school closures in Japan. Schult et al. (2021) noted that eight-and-a-half weeks of school closure led to 0.09 Standard Deviation (SD) and 0.03 SD decrease in maths scores of Grade 5 primary school children. Sabates et al. (2021) identified that children's numeracy level declined in the transition between complementary basic education and government school due to school closures in Ghana. Ardington et al. (2021) reported that Grade 2 and Grade 4 primary school children experienced learning loss in reading in South Africa.

School closures in Turkey

The 2019/20 instructional year began on 9 September 2019. The outbreak of COVID-19 emerged in Wuhan, China, and then quickly turned into a pandemic and spread to the rest of the world. As soon as the first case was detected in Turkey on 13 March 2020, the Ministry of National Education closed all schools from kindergartens to high schools. After the school closure, the ministry decided to deliver all of the curriculum through distance instruction and activated a portal called EBA (Web of Education and Communication). From March 2020 to June 2020, teaching and learning activities were carried out via EBA. By mid-June, the 2019/20 instructional year ended and summer holidays started. The 2020/1 instructional year began on 31 August 2020. However, the ministry decided that all of the classes should be divided in half, with the first group attending primary school on Monday and Tuesday, and the second group attending on Thursday and Friday. The number of COVID-19 cases reached a sudden peak in November 2020, which led the ministry to close schools again. All primary school children continued

receiving instructional and curricular activities through EBA until 1 June 2021. From 1 June to 2 July, primary school children attended school only two days a week and summer holidays started. As a result, from 13 March 2020 to 2 July 2021, Turkish primary school children were dependent on the distance learning portal, EBA. Turkey is one of the OECD countries where schools were closed for the longest time, after Mexico (ERG, 2021). The magnitude of learning loss among Turkish primary school children is therefore worth reporting.

Purpose of the research

During school closure, primary school students stayed away from their teachers and classrooms; they remained in their homes and had to receive instruction with less care, support, guidance and help, via the screens of digital smart devices. Therefore, the home learning environment became an essential part of children's learning, rather than a complementary part. The socio-economic status of the parents is a fundamental component of the home learning environment. Parents with higher socio-economic status provided internet connection, computer and other smart digital devices enabling connection to online learning environments, and reinforcing and supporting their children's learning, allocating more time for them. Hence, socio-economic status may have a mediating role in learning loss of mathematical reasoning owing to school closures.

Primary school students only saw their teachers via their screens. This deprivation brought self-regulated learning to the fore. Self-regulated learning improves with age: children can reflect more on tasks and focus on the instructional tasks delivered through screens as they become older (Zimmerman, 1990). Age is also closely related to attention span. Focusing on the screen at home is more demanding than being in a classroom and interacting with a teacher and peers. As children grow up, they can extend their attention span. Therefore, age was contemplated to mediate the causal relationship. Finally, achievement level may have potential to mediate. However, as it was impossible to collect data on this, this was not addressed in the research (Batejat et al., 1999; McClelland et al., 2013).

The impact of short-term school closures was measured and assessed in the relevant literature; however, the impact of long-term school closures and the overview due to school closures are missing. Turkish primary school children experienced one of the longest school closures in the world. Thus, the impact of long-term school closures on learning loss can be measured and determined in the context of mathematical reasoning. For this reason, the following hypotheses were developed:

1. School closure due to the COVID-19 pandemic led to learning loss in mathematical reasoning of primary school children.
2. Socio-economic status and age moderated the casual relationship between school closure due to COVID-19 and scores from the Battery of Mathematical Reasoning Test (BMRT).

Method

Study 1: development of Battery of Mathematical Reasoning Test

The purpose of Study 1 was to develop the BMRT and report its internal consistency. The BMRT was developed in four stages. First, the relevant literature about mathematical reasoning and the *Mathematical Vocabulary Book* (DfES, 2000) were investigated to develop and design items in the battery according to the age of primary school students. Mathematical vocabulary arranges and presents the skills that can be gained at which age. Hence, it enabled determination of how items were developed. Skills that were included in the BMRT are displayed in Table 1.

It was decided that each of the sub-batteries for the grades would consist of 10 tasks. Problem scenarios were designed and written for each skill from the mathematical vocabulary. The problem tasks were supported by visuals; hence, texts and visuals were integrated. As a result, a draft of the BMRT with 4 sub-batteries and 40 items was developed. The BMRT was examined by 10 primary schoolteachers as to whether the tasks were easy to understand for a primary school student. The BMRT was checked by a Turkish-language expert who assessed whether the texts were easy to comprehend, and by a graphic design expert who assessed whether the visuals were designed based on graphic design rules. It was updated in accordance with feedback from the primary schoolteachers, the Turkish-language expert and the graphic design expert. After the initial draft of the BMRT was designed, ethical issues were taken into

consideration. First, a protocol which included information about the aim and data collection procedure was prepared and submitted to the local education authority in Artvin, Turkey. A panel scrutinised the protocol and the draft of the BMRT. The panel approved the protocol and gave official and ethical approval.

Table 1. Skills included in the BMRT (Source: Authors, 2022)

Grades	Skills	Number of Tasks
Grade 1	Count back	1
	Count up	1
	More, less, many	2
	How many are left over	1
	Equals	1
	Add, more, plus	2
	Subtract, take (away), minus, leave	1
	how many fewer is ... than	1
Grade 2	Count back, Count ones, twos, threes,	1
	Count back from to	
	Multiply of	1
	Odd, even	1
	Fraction	1
	How many is more than ... ?	1
	How many is fewer than ... ?	1
	Divide, divided by, divided into	1
	Groups	1
	How many more make	1
	Make sum, total	1
Grade 3	Count in ones, twos, threes, fours, fives	2
	Once, twice, three times ... ten times	2
	Equal groups of ...	2
	How many more is than ... ?	1
	Make sum, total	2
	How many are left	1
Grade 4	Fifth, tenth, twentieth	1
	How much more/less ... is	1
	How much is left	1
	Half, quarter, eighth	1
	Once, twice, three times ... ten times ...	2
	One each, two each, three each ...	2
	Sum, total, altogether	2

In March and April 2019, primary schools in Artvin were visited to explain the aim of BMRT and the data collection process to primary schoolteachers and head teachers. A total of 21 primary schoolteachers from five primary schools consented to student participation in Study 1. The students were then met and explained what they would have to do; they were asked to take a letter to their parents to gain parental consent. The letter included information about the aim of the research and what the students needed to do, and the parents were asked to sign if they accepted the conditions. In total, 451 letters were signed and received.

The BMRT was copied in colour, and the sub-battery of the test was given to children of the relevant age. The participant children were given instructions on what they would need to do and how to respond to the tasks. The average duration of test completion was about 15 minutes, after which they returned the answer sheets.

Each correct response was coded as '1' and each wrong response was coded as '0'. Then item analysis was carried out with item–total correlation, and internal reliability was analysed for each of the items. Results of item analysis for the sub-test for Grade 1 are displayed in Table 2.

Table 2. Results of item analysis for the sub-test for Grade 1 (Source: Authors, 2022)

Item	Mean	SD	Corrected item–total correlation	Cronbach alpha if item deleted
1	0.93	0.43	0.31	0.81
2	0.77	0.55	0.47	0.79
3	0.62	0.60	0.65	0.77
4	0.39	0.59	0.49	0.79
5	0.45	0.50	0.53	0.79
6	0.64	0.48	0.52	0.79
7	0.50	0.50	0.54	0.78
8	0.48	0.48	0.69	0.77
9	0.58	0.79	0.37	0.82
10	0.48	0.50	0.36	0.80

Results of item analysis indicated that all of the tasks were adequately correlated with the total score, due to higher correlation than 0.30. For Cronbach alpha, if the item is deleted, it should not lead to an increase in overall consistency. The overall Cronbach alpha coefficient of the sub-test for Grade 1 was found to be 0.83.

As can be seen from Table 3, the tasks were positively correlated with the total score and deleting any item did not increase the overall Cronbach alpha. Therefore, the items were related to mathematical reasoning as a single specific domain. As a result, it was concluded that the BMRT yields reliable results in assessing mathematical reasoning of Grade 2 primary school students. The overall Cronbach alpha coefficient of the sub-test for Grade 2 was found to be 0.83.

Table 3. Results of item analysis for the sub-test for Grade 2 (Source: Authors, 2022)

Item	Mean	SD	Corrected item–total correlation	Cronbach alpha if item deleted
1	0.52	0.77	0.30	0.75
2	0.57	0.50	0.36	0.80
3	0.63	0.50	0.39	0.80
4	0.36	0.50	0.41	0.76
5	0.84	0.37	0.49	0.75
6	0.10	0.22	0.30	0.73
7	0.47	0.51	0.51	0.74
8	0.68	0.47	0.56	0.79
9	0.16	0.37	0.58	0.75
10	0.16	0.37	0.57	0.83

Results displayed in Table 4 reveal that there was no task whose corrected item–total correlation was lower than 0.30. Based on this structure, all the tasks in the sub-test for Grade 3 measure the same disposition: mathematical reasoning. As for internal consistency, the Cronbach alpha values ranged between 0.74 and 0.84, which is higher than the threshold value of 0.70. Hence, it was concluded that all the tasks solely measure mathematical reasoning and produce reliable results for the measurement of mathematical reasoning among Grade 3 primary school children. The overall Cronbach alpha coefficient of the sub-test for Grade 3 was found to be 0.85.

Table 4. Results of item analysis for the sub-test for Grade 3 (Source: Authors, 2022)

Item	Mean	SD	Corrected item-total correlation	Cronbach alpha if item deleted
1	0.76	0.43	0.53	0.84
2	0.46	0.47	0.50	0.75
3	0.73	0.44	0.40	0.79
4	0.18	0.39	0.60	0.77
5	0.18	0.39	0.60	0.76
6	0.65	0.49	0.60	0.77
7	0.62	0.48	0.59	0.75
8	0.35	0.49	0.44	0.74
9	0.58	0.79	0.40	0.74
10	0.47	0.50	0.33	0.79

Results in Table 5 proved that all Cronbach alpha coefficients for the items are lower than the overall Cronbach alpha value. The overall Cronbach alpha coefficient of the sub-test for Grade 4 was found to be 0.87. The Cronbach alpha coefficient of the sub-test for Grade 4 was higher than 0.70, the threshold of reliability. Thus, the sub-test for Grade 4 is a reliable instrument in measuring the mathematical reasoning of Grade 4 primary school students, and it measures a single specific disposition: mathematical reasoning (Field, 2009; Nunnally and Bernstein, 1994).

Table 5. Results of item analysis for the sub-test for Grade 4 (Source: Authors, 2022)

Item	Mean	SD	Corrected item-total correlation	Cronbach alpha if item deleted
1	0.37	0.50	0.57	0.82
2	0.25	0.44	0.30	0.84
3	0.40	0.49	0.54	0.82
4	0.44	0.39	0.49	0.83
5	0.37	0.50	0.47	0.83
6	0.56	0.51	0.47	0.82
7	0.50	0.52	0.54	0.80
8	0.44	0.51	0.65	0.82
9	0.56	0.51	0.60	0.79
10	0.69	0.48	0.36	0.84

As a result, the BMRT consisting of four sub-tests with 10 tasks can produce reliable results for measurement of the mathematical reasoning of primary school students from Grade 1 to Grade 4.

Study 2: revealing impact of school closures due to the COVID-19 pandemic on learning loss in mathematical reasoning

Design of the study

There was no ability to control and manipulate the school closures due to COVID-19, the independent variable in the research, and occurrence of its manifestations were outside deliberate intervention. Therefore, *ex post facto* research was used to design Study 2 (Kerlinger, 1966).

Measurements

Mathematical reasoning was assessed through the BMRT, which consists of 10 tasks on mathematical reasoning for each of the four grades. The socio-economic status of the participant students was assessed with a two-factor index by Hollingshead (1965). Hollingshead's two-factor index encompasses maternal education and occupation, and paternal education and occupation. It assigns a value to each occupation, from 1 to 9, while it gives a number, from 1 to 7, for each level of parental education. In the two-factor index, occupational score is weighted by 5, whereas educational score is weighted by 3. After weighted scores are found for mother and father, maternal and paternal scores are added, and then the total is divided by 2. As a result, parental background is found. In the study, the two procedures for Hollingshead's two-factor index were followed and parental backgrounds of the participant children were converted to a composite score and continuous variable.

Data collection process

The Turkish education system was affected by the COVID-19 pandemic, and a proposal was prepared and submitted to the Ministry of National Education. A panel from the ministry dealt with the proposal and approved it in terms of ethical considerations and official permission. Due to the fact that all primary schools in Turkey were closed, it was impossible to collect data through face-to-face meetings with the participants. Thereby, it was decided that the data would be gathered through Google Docs. Items of the BMRT and questions about paternal education and profession were uploaded to Google Docs. On the first page of the Google Docs, the aim of the research, and the procedure about how to respond to items on the BMRT were introduced. Questions related to parental background were inserted on the second page. The third page included the BMRT items. It was planned that the first round of data collection would be conducted in May and June 2020 to coincide with the completion of teaching of the mathematical reasoning skill in May 2020. Links to Google Docs were shared with primary school teachers to send to parents whose children were attending primary school. First, parents were asked to respond to the questions about their socio-economic status, and their children's age and gender. Then, the children were asked to answer relevant questions on the BMRT.

A total of 415 parents responded to the questions about socio-economic status, and their child's age and gender before their children completed the tasks on mathematical reasoning. Of the children who completed the BMRT, 90 were in Grade 1, 106 were in Grade 2, 117 were in Grade 3 and 102 were in Grade 4. As a consequence, Cohort 1 of the research included 415 parents and children, and the first cycle of data collection ended at the end of June 2020. The second cycle of data collection was launched on 20 May 2021 and ended on 15 July 2021. The previous method for data collection was followed and, as a result, 964 primary school students and their parents participated in the research. Therefore, Cohort 2 consisted of 964 participants. Of the students who participated in Study 2, 225 were in Grade 1, 260 were in Grade 2, 249 were in Grade 3 and 230 were in Grade 4.

Information about Cohort 1: pre-pandemic group

Cohort 1 students started primary school on 9 September 2019. They attended primary school and received face-to-face instruction until 13 March 2020, when the first COVID-19 case was identified in Turkey. They attended curricular and classroom activities for more than six months. After that, they continued to learn curricular skills and knowledge through EBA. For these reasons, Cohort 1 was labelled as the pre-pandemic group.

Information about Cohort 2: post-pandemic group

Cohort 2 children attended school two days per week from 31 August 2020 to the beginning of November 2020. They were taught curricular skills and knowledge through EBA between November 2020 and the end of May 2021. After May 2021, they attended schools two days per week. They never received full-time face-to-face instruction during the 2020/1 instructional year. Their school life was dramatically disrupted by the pandemic; and for this, Cohort 2 children were labelled as the post-pandemic group.

Data analysis

Study 2 addressed how school closures due to the COVID-19 pandemic, an antecedent variable of the study, influenced learning loss in mathematical reasoning in primary school children, the consequent variable. Therefore, Study 2 also targeted both identification of learning loss and determination of variables mediating the causal mechanism between school closure due to the pandemic and learning loss in mathematical reasoning. ANCOVA co-variant analysis was used to identify whether there was significant difference between Cohort 1 and Cohort 2 in scores from the BMRT. ANCOVA results are shown in Table 6.

Table 6. ANCOVA results for the BMRT scores (Source: Authors, 2022)

Group	N	Mean	SD	Std. Error	F	P	η^2
Cohort 1	415	7.55	2.31	0.11	15.72	0.00	0.86
Cohort 2	964	6.70	2.74	0.08			

Based on the results in Table 6, the mean and standard deviation of Cohort 1 students were 7.55 and 2.31, while the mean and standard deviation of Cohort 2 were 6.70 and 2.74. There was a significant difference between Cohort 1 student scores from the BMRT and scores for Cohort 2 students ($F = 15.72$, $p < 0.05$, $\eta^2 = 0.86$). This result means that gains in mathematical reasoning skills among Cohort 2 students were significantly lower than gains in mathematical reasoning skills among Cohort 1 students, so Cohort 2 students experienced learning loss. Moreover, η^2 was .86, indicating that there was a large effect size from school closures. As a consequence, Hypothesis 1 was confirmed.

After identification of causal impact and its effect size through ANCOVA analysis, mediation analysis was conducted to determine causal mechanism variables which mediate the causal mechanism between school closure due to the COVID-19 pandemic and learning loss in mathematical reasoning. Socio-economic status and age were assigned as mediator variables in the causal model. The PROCESS macro developed by Hayes (2015) was used to conduct moderation analysis. Moderation analysis results are shown in Table 7.

Table 7. Total effect of the model (Source: Authors, 2022)

Model	Estimate	$R^2_{X.MY}$	SE	t	P→LLCI→ULCI
Cohort _(1,2) (X) → socio-economic status (M ₁) and Age (M ₂) → mathematical reasoning (Y)	0.84	0.32	0.15	−5.40	0.00→−1.14→−0.54

Results in Table 7 reveal that the standardised beta coefficient of the model was strong and significant ($\beta = 0.84$, $t_{(1365)} = -5.40$, $p < 0.01$, path c).

Results for the direct influence of Cohort (X) on mathematical reasoning (Y) are displayed in Table 8.

Table 8. Results of direct effect (Source: Authors, 2022)

Model	Estimate	$R^2_{X.Y}$	SE	t	P→LLCI→ULCI
Cohort _(1,2) (X) → mathematical reasoning (Y)	0.82	0.31	0.15	−5.28	0.00→−1.10→−0.51

Results in Table 8 indicate that the direct effect of Cohort (X) on mathematical reasoning (Y) was considerably strong and significant ($\beta = 0.82$, $t_{(1365)} = -5.28$, $p < 0.01$, path c') and 31 per cent of the

variation in the scores for mathematical reasoning was explained solely by Cohort_(1,2), the independent variable in the study.

The effects of socio-economic status and age, mediator variables in the study, were analysed, and results are shown in Table 9.

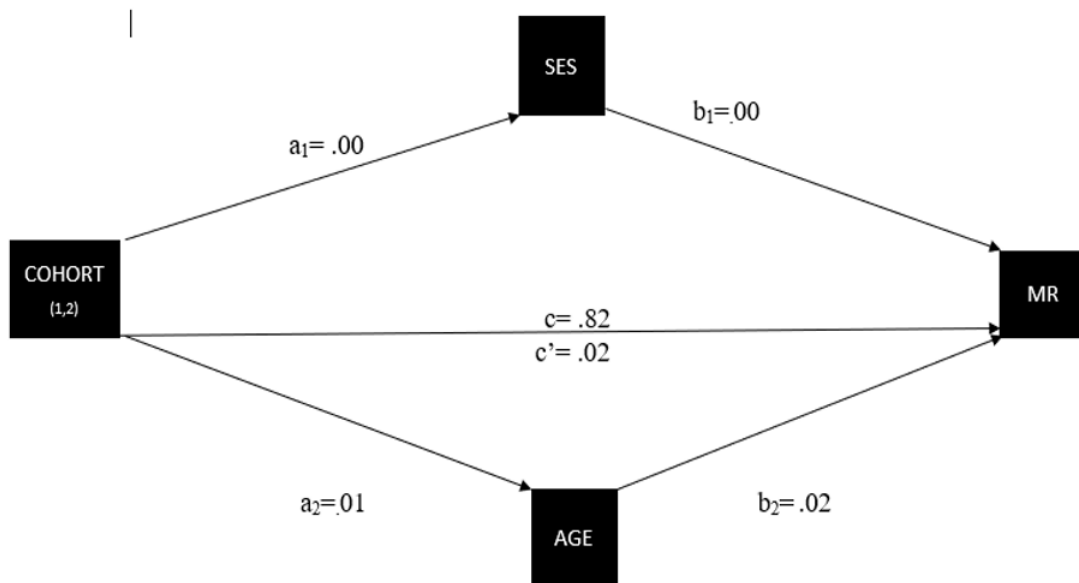
Table 9. Indirect effects of socio-economic status and age (Source: Authors, 2022)

Model	Estimate	SE	P→LLCI	ULCI
Cohort _(1,2) (X) → socio-economic status (M ₁) → mathematical reasoning (Y)	0.00	0.00	0.92→−0.01	0.01
Cohort _(1,2) (X) → Age(M ₂) → mathematical reasoning (Y)	0.02	0.02	0.39→−07	0.02

Socio-economic status does not have a mediating role in the effect of Cohort_(1,2) on mathematical reasoning and its effect was not significant ($\beta = 0.01$, $p > 0.05$, 95% CI [−0.01, 0.01], path c'). As for age, it has a very weak mediating role but was not significant ($\beta = 0.02$, $p > 0.05$, 95% CI [−0.07, 0.02], path c').

The model constructed based on direct, indirect and total effects is presented in Figure 1.

Figure 1. Direct, indirect and total effects of Cohort (1,2) on mathematical reasoning (Source: Authors, 2022)



SES: socio-economic status; MR: mathematical reasoning

In sum, Cohort_(1,2) had a remarkable and significant effect on mathematical reasoning, and the effect was significant when neither the socio-economic status nor the age mediated the influence of Cohort_(1,2) on mathematical reasoning. Therefore, Hypothesis 2 was rejected.

Discussion

Overall, the results of the study indicate that the cohorts, which were constituted based on the status of face-to-face instruction or attending distance education owing to school closures, substantially

influenced the mathematical reasoning skills of the participant primary school children. In addition, the socio-economic status and the age did not mediate the effect of the cohorts on mathematical reasoning. In other words, school closures due to COVID-19 led to significant learning loss, and Turkish primary school children experienced learning loss owing to school closures irrespective of their socio-economic status and age.

Learning refers to the process in which new insight, knowledge, skills and values are gained, and it implies permanent change in an individual's cognitive, social-emotional and behavioural performance through practice and experience (Schunk, 2012). Human learning takes place in a definite cultural environment, and human beings learn from one another and through others, unlike other animals. Therefore, social interaction plays a key role in the transmission of knowledge, skill and behaviour (Tomasello et al., 1993). In cultural environments, human learning occurs in various ways by imagining the roles and perspectives of others (Mead, 2015; Piaget, 1959), attributing mental states to others (Wellman et al., 2001), simulating mental states of others (Harris, 2000), engaging in joint attention with others (Bruner, 1983), intersubjectively participating with others (Trevvarthen, 1995) and conceiving of others as people (Hobson, 1990). Classroom settings are cultural environments where learning occurs in various ways as a result of intense social interaction between child and teacher, and between child and child. In primary school classrooms, students can internalise all the demonstrations, instructions and performance by the teacher so as to add knowledge, skills and behaviours to previously learnt knowledge, skills and behaviours (Tomasello et al., 1993). Social interaction between child and teacher allows primary school children to internalise what they experience in classroom settings, because social interaction enables them to react and reproduce what is demonstrated, and teachers can give feedback on their reactions and performance. As a consequence, classrooms make student learning easier by facilitating social-cultural features of human learning.

School closures due to the COVID-19 pandemic deprived primary school students of the experience of imagining the teacher's roles and perspective, engaging in joint attention and intersubjective participation. In other words, the school closures disrupted the cultural and social process for learning opportunities, and caused learning loss in the mathematical reasoning skills of primary school students. Cultural and social dimensions of learning are absent in the online learning environment, and the online learning environment impedes rather than facilitates imagining roles and perspectives, attribution and simulation of mental states, engagement in joint attention and intersubjective participation through social interaction between student and teacher.

Mathematical reasoning encompasses a wide range of skills, from assessment of mathematical arguments to use of mathematical operations (Kramarski and Mevarech, 2003; Stein et al., 1996). Gaining mathematical reasoning skills requires intense student-teacher interaction and schooling. Even though the online learning environment communicates the skills in mathematical reasoning from teacher to students, it offers shallow student-teacher interaction. Cohort 1 primary school students were in classrooms and schools for six months, whereas Cohort 2 did not experience complete social interaction with their peers and teachers owing to school closures. Therefore, school closures substantially decreased the mathematical reasoning skills of Cohort 2 students compared to Cohort 1 primary school students.

The fact that school closures during the pandemic resulted in learning loss in the mathematical reasoning skills of primary school children can be explained by the Vygotskian theory of development. According to Vygotsky (2012), learning occurs when a learner can do and perform a task that was not previously performed. This permanent change in behaviour emerges through assistance from others who are more knowledgeable and more skilled. In other words, learning is the process in which the learner becomes able to fulfil certain tasks under direction and collaboration with more capable adults or peers. Rich collaboration, guidance, help and direction are embedded in classroom settings, while the online learning environment is deprived of them. The teachers' direction, guidance and help from a screen is of little use for primary school students in understanding curricular mathematics activities and fostering mathematical reasoning skills. Therefore, it can be argued that school closures disrupted the directions, instructions, guidance and collaboration of teachers in teaching mathematical reasoning skills. The teacher is the most important component of the learning environment. Their instruction and interaction with students play key roles in achievement. Changing teacher instruction and interaction with students has crucial implications for efficiency of teaching activities and learning performance of students (Rivkin et al., 2005; Hanushek, 2011; Hanushek and Rivkin, 2012). Transferring the learning place from the classroom to online learning involved formidable results for learning loss in mathematical

reasoning, because of the fact that this transfer caused changes in teacher instruction and interaction with students. While Cohort 1 received teacher instruction and experienced real social instruction with their teachers for six months, Cohort 2 were deprived of real classroom instruction and social interaction with their teachers. This change between the two cohorts led to different learning performance.

The effect of school closures due to the COVID-19 pandemic on mathematical reasoning can be argued by the distinction between fluid intelligence and crystallised intelligence formulated by Cattell (1963). While fluid intelligence has more biological roots, crystallised intelligence is dependent on culture and individual history, language and experience. Crystallised intelligence is fostered through social transmission, so schooling makes remarkable contributions to improvement of crystallised intelligence (Blair, 2006; Horn and Blankson, 2012). Additionally, crystallised intelligence is related to maths achievement (Floyd et al., 2003; Kaufman et al., 2009). Mathematical reasoning requires both remembering stored knowledge and conducting operations, most of which were previously learnt. Therefore, remembering and storing knowledge entails social experience and interaction, so it can be argued that crystallised intelligence plays an important role in improving mathematical reasoning skills. Online learning environments negatively influenced the mathematical reasoning skills of Cohort 2 primary school students because of the fact that mathematical reasoning is partly crystallised intelligence and online learning environments deteriorated crystallised intelligence linked to the lack of social transmission and interaction for Cohort 2 primary school students.

As for socio-economic status and age, two mediator variables in the study, results showed that socio-economic status did not have an indirect effect on mathematical reasoning. This result has seminal implications because socio-economic status does not mediate causal associations between the cohorts and mathematical reasoning skill. Therefore, school closures led to learning loss in mathematical reasoning skills regardless of the socio-economic status of participant primary school students, while socio-economic status was previously proposed to buffer the negative impact of school closures. It was observed that age had a very small and insignificant mediating effect. As a consequence, replacing student-teacher interaction in the classroom setting with the online learning environment, which obstructs directions, instructions, guidance and collaboration provided by teachers, created remarkable learning loss in mathematical reasoning regardless of socio-economic status and age.

The results of the study does not align with the relevant literature on socio-economic status, which reported that socio-economic status is a seminal indicator in academic achievement (McLoyd, 1998; Sirin, 2005). Previous research was conducted in classrooms, and higher socio-economic status made students successful in classroom interactions. However, the present study was conducted on students who received instruction without classroom interactions. Therefore, there is a sharp contrast between the conditions in the previous research and that of the present study. The socio-economic status did not manage to mediate the causal relationship in the online learning environment. Age also did not play a mediating role. There is a remarkable association between age and self-regulated learning. The more age increases, the more self-regulated learning develops (Zimmerman, 1990). Hence, it was included in the analytic procedure to explore its mediating power on the causal relationships between learning loss of mathematical reasoning and school closures. It had been considered that the older participant students would not be as negatively influenced as the younger participant students. Online learning environments made age pointless in terms of self-regulated learning. As a result, age variable did not manage to mitigate the negative effect of school closures.

The results of the study comply with previous studies aiming to disclose learning loss stemming from school closures in different learning domains and different countries (Ardington et al., 2021; Asakawa and Ohtake, 2021; Blaskó and Schnepf, 2020; Di Pietro et al., 2020; Engzell et al., 2021; Kuhfeld et al., 2020; Maldonado and De Witte, 2020; Sabates et al., 2021; Schult et al., 2021; Tomasik et al., 2021; UN, 2020).

Conclusions

As a result of the overall research findings, it was concluded that school closures due to the COVID-19 pandemic caused learning loss in mathematical reasoning skills of Cohort 2 primary school students based on comparison with Cohort 1 students, while socio-economic status and age did not mediate the impact of school closures. Significant decreases in Cohort 2 students' mathematical reasoning scores in comparison with Cohort 1 students were ascribed to being deprived of condensed student-teacher interaction, and gaining insufficient help, care and support from their teachers in online learning

environments. Moreover, socio-economic status and age did not mediate the causal relationship. This result indicates that primary school students in Cohort 2 experienced deprivation from the social interaction with their teachers and were affected by the school closures.

Recommendations

Governments around the world reopened schools, and they intend to keep schools open. Thus, it is worth researching whether opening schools will compensate for learning loss. Human behaviour is a result of complex influences, which cannot be explained by a single variable. The present study addressed the school closures due to the COVID-19 pandemic as an independent variable, mathematical reasoning as a dependent variable, with socio-economic status and age as mediator variables. Future research can include different mediator variables in the model, such as parent-child interaction, emotional intelligence, family size and birth order, to reveal the mediation power of these variables. The impact of school closures on different dependent variables, such as reading and social studies, can be scrutinised by establishing different causal models in future research.

In the present study, the level of student achievement could not be included due to lack of data collection. In future research, level of student achievement may be included and analysed to reveal impact of school closures due to COVID-19 on learning loss of mathematical reasoning.

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Declarations and conflicts of interest

Research ethics statement

The authors declare that research ethics approval for this article was provided by the Ministry of National Education ethics board.

Consent for publication statement

The authors declare that research participants' informed consent to publication of findings – including photos, videos and any personal or identifiable information – was secured prior to publication.

Conflicts of interest statement

The authors declare no conflict of interest with this work. All efforts to sufficiently anonymise the authors during peer review of this article have been made.

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