



Tracing students' mathematics learning loss during school closures in teachers' self-reported practices

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ABSTRACT

The study explored how mathematics learning loss took place among Turkish middle school students during the COVID-19 school closures through mathematics teachers' self-reported practices, challenges, and efforts while they were trying to support their students' learning. Interviews with 19 public and 9 private middle school mathematics teachers indicated that there were certain differences in teachers' practices and revealed the existing inequalities among the schools, classrooms, and students. Students' lack of participation, teachers' limited use of methods to teach mathematics, the socio-economic status of families and their lack of collaboration with teachers were among the reasons for mathematics learning loss.

1. Introduction

1.1. Learning loss during the school closures

Teachers and students have been struggling with the psychological, physical, social, and economical consequences of the COVID-19 pandemic and the school closures since March 2020. Several measures, such as distributing online instructional resources, broadcasting the educational content via TV or radio channels, promoting the use of online learning management systems, and organizing/encouraging asynchronous or synchronous lessons, were taken by countries to provide students with learning opportunities (Schleicher and Reimers, 2020). Nonetheless, such measures do not simply mean that students have access to an effective learning environment.

The pandemic in general and school closures in particular have increased inequality especially in students' access to learning opportunities (Andrew et al., 2020; Bakker and Wagner, 2020; Hodgen et al., 2020; Jæger and Blaabæk, 2020). The role of the school as an equalizer for educational opportunities for students was reduced during the pandemic (Andrew et al., 2020) and the learning gap between the students from high earning homes and disadvantaged homes has increased

largely (Akmal and Pritchett, 2021; Van Lancker and Parolin, 2020). Students from disadvantaged homes could not access all or most of the educational opportunities during school closures across the world (Andrew et al., 2020; Engzell et al., 2021; Hossain, 2021; Sabates et al., 2021). Family environment, which is a highly variable factor, became more influential in students' learning as the influence of the school decreased (Andrew et al., 2020; Tomasik et al., 2020) along with several factors, such as students' learning styles, characteristics, and motivation (Tomasik et al., 2020).

The pandemic brought uncertainties for the families and loss of income for many of them (Daniel, 2020; Tomasik et al., 2020; Van Lancker and Parolin, 2020), where children's educational needs became less important compared to the basic needs of the family. The education level and job security of the families before and during the pandemic influenced students' learning during school closures (Tomasik et al., 2020) because of the existing and pandemic-time differences in home learning environment and resources, and the consequent inequalities (Andrew et al., 2020; Sabates et al., 2021; Tomasik et al., 2020). The lack of learning support and activities at home in addition to the lack of access to technology caused substantial learning loss (Sabates et al., 2021). A study in the U.K. by Andrew et al. (2020) revealed that a considerable

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number of students did not participate in online lessons and students spent less hours for learning at home compared to the school time. The same study also found that while the school closures prioritized the availability of technology and the internet for the students, to what extent students have a learning space and resources at home was understated despite its importance. In addition to these differences, schools and classrooms differed in terms of how online instruction was implemented during school closures, which will result in learning gaps for the students (Middleton, 2020).

Learning loss during the pandemic has been the focus of several studies. A relatively short (8 weeks) lockdown in the Netherlands was expected to result in a learning loss equivalent to 20% of a school year and even more for students from disadvantaged families (Engzell et al., 2021). In the USA, projections have addressed that students will have up to 27% learning loss in reading and 50% learning loss in mathematics compared to a pre-pandemic typical school year (Kuhfeld et al., 2020). Similarly, it was reported that learning will decrease 0.3–0.9 years during the pandemic in Turkey as a result of both failing to learn what needs to be learned and forgetting existing learning (TEDMEM, 2020). Even when the students had access to online tools, a potential learning loss was expected compared to the pre-pandemic school time (Wyse et al., 2020). It is also likely that students who were preparing for a large-scale examination were affected because they had to learn differently with or without access to the learning resources and tools (Middleton, 2020).

Understanding the magnitude of learning loss, the “learning that is not taking place while schools are closed, learning that is forgotten” (Sabates et al., 2021, p. 2) is important because learning loss may have long-term effects on students’ participation in society in the future (Tomasik et al., 2020; Andrew et al., 2020). The learning loss due to school closures may not be compensated especially in education systems where teachers have to cover a loaded curriculum (Kaffenberger, 2021) and where there are many students who, in normal circumstances, cannot learn with the existing curriculum pace (Kaffenberger and Pritchett, 2021). Additionally, the extent of the learning loss may not be similar for the students with different backgrounds.

1.2. Teachers’ practices and concerns during school closures

Schools were closed rapidly and generally indefinitely in the middle of Spring 2020 semester in almost all countries. The immediate reaction was to conduct *remote teaching* (RT) by transferring or adapting the content to the available online tools without sufficient planning and infrastructure. Teachers were not prepared for such massive and long school closures in terms of online teaching skills (Alper, 2020; Middleton, 2020; Özdoğan and Berkant, 2020), which resulted in additional stress for them (Trust and Whalen, 2020; Yang, 2020). Many teachers reported that they did not have sufficient tools and internet connection for RT (Barret, 2021; See et al., 2020;). Teachers also had to deal with external factors, such as students’ limited access to the technology, rapidly changing policy requirements, and uncertainty of the near future (Code et al., 2020; Kim and Asbury, 2020; Trust and Whalen, 2020).

The initial response of teachers when the uncertainties were reduced was to develop strategies to provide learning opportunities for the students based on their learning needs (Kim and Asbury, 2020). Teachers initially depended on the existing online options for the RT and tried to learn more about other options either through their own efforts (Trust and Whalen, 2020) or as a part of a regional support system (Yang, 2020). There were cases that teachers and students communicated via instant messaging applications for mobile phones even when there were learning management systems including such functions (Taipale, 2021; Yang, 2020). However, teachers had several learning-related concerns as the RT progressed such as students’ limited access to the learning tools and resources, their poor motivation and self-regulation skills for learning, and inadequate or lack of assessment of students’ learning (Alper, 2020; Özdoğan and Berkant, 2020).

Most of the learning-related concerns were related to existing inequalities among the students. Teachers observed that there were students with limited or no access to the online learning resources (Barret, 2021; Code et al., 2020; Kim and Asbury, 2020; Middleton, 2020). The limited learning-related interaction with the students during synchronous teaching did not help teachers respond to students’ needs because they did not have sufficient input from the students (Alper, 2020; Barret, 2021; Özdoğan and Berkant, 2020).

Another important concern was about the assessment of students’ learning. Teachers could not depend on their in-class assessment and observations as they used to do in face-to-face classrooms (Alper, 2020; Barret, 2021; Özdoğan and Berkant, 2020). They were not sure that they were able to monitor students’ learning adequately and have an accurate assessment (Niemi and Kousa, 2020). Teachers who could conduct synchronous teaching had difficulties in observing whether the students were working on the tasks or not especially when the cameras were off (Barret, 2021; Niemi and Kousa, 2020). Despite the concerns for assessment, teachers think that assessing students somehow would be unfair for the students with limited access to the learning resources (Barret, 2021).

Teachers were worried that students without essential self-regulation and self-study skills would have difficulties managing learning remotely (Alper, 2020; Özdoğan and Berkant, 2020; Yang, 2020). Students might not study properly and lose their motivation due to the policies granting them with a pass to the next grade level or accepting their before-school closure grades as the final grade of the course (Barret, 2021; Code et al., 2020).

1.3. Remote teaching in Turkey

School closures due to the pandemic started on March 12th, 2020 in Turkey with the Ministry of National Education’s (MEB) announcement that public and private schools would be closed for two weeks. The initial idea was that schools would open after this two-week closure. However, on March 25th, MEB announced that schools were closed until the end of April. At the end of April, MEB announced that schools were closed until the end of May, and then eventually the end of the semester.

MEB already had a learning management system (EBA) for about 10 years including virtual applications, online assignments, and online examinations to be used by all primary, middle, and high school students and teachers. Teachers and students could access the EBA via computers, tablets, or phones. Students were directed to study the EBA resources and follow the video lessons organized for all grade levels via a special TV channel, the EBA-TV. While public schools directed students to study EBA-related resources, private schools used their own learning management systems (such as Google Classroom and Moodle) and different online meeting tools (such as Google Meet, Zoom, and Microsoft Teams) to conduct synchronous lessons. In the middle of April, MEB announced that EBA had a new tool which could be used for synchronous lessons in public schools first, for 8th and 12th grades, and then, gradually for all grades. Until this time, there were no specific instructions for teachers and administrators about how they would conduct RT and what was expected of them. Public schools’ administrations were suggested to arrange daily online lesson schedules on EBA. Students and teachers tried to follow these schedules as much as they could. Within this uncertainty, private schools acted fast, organized their schedules mostly in line with pre-pandemic time, and started mostly synchronous lessons for the students. Some private schools reduced the lesson hours to 30 minutes.

1.4. The study

Studies about teachers’ practices and concerns during the RT revealed that students had difficulties in accessing the learning opportunities. Therefore, learning loss was inevitable during the school closures. This learning loss was generally predicted, but reasons for this loss

as observed and experienced by the teachers, who have the knowledge and insight about their students, were not explored much. The present study delved into how mathematics learning loss took place among middle school students in Turkey during school closures in Spring 2020 through public and private middle school mathematics teachers' self-reported practices, challenges, and efforts while they were trying to support their students' learning. The initial assumption was that learning loss was mostly due to existing socio-economic inequalities among students and schools. We also assumed that there would be interrelated factors that had the potential to affect teachers' practices during the RT. Based on these assumption and the literature, the following questions were sought:

1. How did teachers support students' mathematics learning during the school closures in Turkey due to the COVID-19 pandemic?
2. What were the factors that influenced teachers' RT and support practices, and students' mathematics learning loss?

School closures continued in the following school year. At the time of the submission of this study, schools were opening for face-to-face instruction in Fall 2021. Although the study focused on the initial school closure, our assumption was that the factors that affected students' learning loss (as revealed in the analyzes) were not improved much in the following academic year. Therefore, learning loss most probably continued.

2. Method

The study employed phenomenology (Creswell and Poth, 2018) because the aim was to explore middle school mathematics teachers' lived RT experiences during school closures in the Spring 2020 semester due to the pandemic. The focus was on their teaching practices during the RT, how they tried to support students' learning, and what factors affected their efforts to reduce students' learning loss during the process. Through these experiences, we aimed to uncover the reasons for students' learning loss in mathematics.

2.1. Participants and school contexts

The study took place towards the end of the Spring 2020 semester when teachers were busy with conducting RT and concluding the semester. We decided to access participants whom we had personal contacts, and therefore, who would volunteer for the study at an extraordinarily busy time of the year to talk about their experiences. This led us to contact the mathematics teachers we had varying degrees of communication in the past via e-mail and ask if they would like to participate in the study. Some of these participants suggested other mathematics teachers as potential participants who were interested in the study. We also contacted these potential participants via e-mail for the interviews. Participants were 28 (21 female, 7 male) middle school (grades 5–8, ages 10–13) mathematics teachers who volunteered for the study. The participants were working at public (N = 19) and private (N = 9) schools in 12 different cities in Turkey. Most of the public school teachers were teaching in rural schools and/or schools with low socio-economic status (SES) students. Private school teachers were teaching in large cities. Most of the participants were in the first five years of teaching (N = 12), two teachers had more than 15 years of experience.

Private schools in Turkey provide better facilities and technological opportunities for students and teachers, and require a yearly tuition. Students come from high SES families and have better technological tools and home study environments. Public schools, especially in rural or low SES neighborhoods, have poorer facilities and technological tools. Their students are mostly from low and mid SES families. Public schools are financed by the state.

2.2. Data collection

Data were collected by all three of us with a semi-structured interview protocol of eight open-ended questions and related follow-up questions about the RT practices of mathematics teachers after ethical permissions were granted. We did not ask participants questions directly about mathematics learning loss. Rather, we aimed to explore their experiences in-depth in order to gather more information about the schools, practices, and students, which provided a more comprehensive picture of the learning loss.

Interviews were conducted via Zoom or telephone with 20 teachers. Eight teachers completed the interview protocol with written responses due to conflicts in schedules or lack of sufficient internet access. Interviews were video-recorded based on participants' consent or participants' responses were noted down extensively. The main interview questions and sample follow-up questions are given in [Appendix](#). Interview notes and written responses were sent back to the participants via e-mail after we read them to comment on the accuracy of the notes, explain unclear issues, and provide more information. This process enhanced the depth and breadth of the data set and allowed for a more thorough analyzes.

2.3. Data analysis

An inductive coding process (Miles et al., 2014) was employed for the data analysis because the goal was to describe teachers' lived experiences during a completely new phenomenon and to understand how they made sense of this process especially in relation to the students' learning loss. All three of us participated in all stages of the data analysis. We had six meetings in seven weeks during the data collection and discussed about our initial understanding of the experiences of the participants. This provided us with early ideas about the variety of teachers' experiences, emerging themes, and a saturation point for data collection. When the data collection ended, each of us read our own data set and developed a list of initial codes. We shared and discussed about these lists, which lead to a final list of codes with room for additional codes for the analysis. Then, each of us analyzed our own data set with the final code list. The initial themes, such as "teachers' use of technology" and "students' access to technology", were interlinked with several issues of inequality and mathematics learning loss, which made it difficult to finalize the themes. Therefore, more general themes with several common inequality-related factors in connection to the mathematics learning loss were generated with emphasis on the interlinks. Data analysis process was completed through seven iterative discussions within five weeks.

3. Findings

The analysis revealed certain differences and similarities between public and private school teachers' practices and how they supported their students' mathematics learning. Below, we first present the teachers' practices during school closures for public and private school teachers separately, and we document common concerns and related efforts when they supported students' learning. Then, we focus on the factors that influenced teachers' practices and therefore, students' mathematics learning loss.

3.1. Teachers' support for students' learning

3.1.1. Public school teachers' practices

Public school teachers had a wide range of practices. Most of them were teaching to low SES students. Their practices were highly affected by the students' access to the internet and technology. The first week of the school closure was mostly described as a time teachers tried to figure out what to do, what resources they had, and how they would continue teaching. Teachers expected that the break would be temporary and

they would be back in their classrooms within two weeks: “*We couldn’t do anything for about 2 weeks. We only assigned the students homework before we left. We sent retention tests about prior subjects from both EBA and useful resources we had.*”

MEB announced the guidelines to access EBA-TV in the second week of the closure. Then, most of the teachers tried to call students one-by-one and guide them on how to access EBA-TV broadcasts and the internet resources. Teachers started to think about options for RT because they realized that they were not returning schools for a long time. One of the most common initial actions was to create WhatsApp (WA) groups with the parents and students who had phones with internet connection. The “class teachers”, the teachers who monitored the students in a specific class and coordinated the communication between the parents and the administration for that class, started the WA groups. Mathematics teachers created WA groups for the classes they were the class teachers and they also tried to join the WA groups of other classes they taught. However, many teachers indicated that they could not access some students in the class that they were the class teachers. Many teachers could not access the whole class of students either because the class teacher did not create the WA groups.

Teaching took place via WA communication for most of the public school participants. Teachers sent short explanation of the concepts and questions to solve via the WA groups either as a photo file, or rarely as video or voice records. Then, students solved the questions, took photos of their solutions, and sent them back to the teachers via individual WA communication. However, only few students maintained this communication with the teachers continuously. The following excerpt explains teachers’ practices in detail:

“I [wrote] the explanation of the topics in detail on papers, clarified it with colored pencils with warnings like “this is very important for us”, took its photo, and sent it [to the students]. They wrote it in their notebooks. I wrote and sent the solutions to the questions as detailed as I could, as if I was talking [to the students]. I sent resources such as question books. I sent [notes about] what they should pay attention to [which] type of questions, I sent 2–3 questions each day like this. I did not send videos [because the students] could not watch them. I tried to explain as much as I could on the paper. Students did not have the opportunity to watch the video.”

Public school teachers also sent questions for students to solve via the EBA platform. Some teachers indicated that students had some familiarity with EBA because they had already been using EBA to support their teaching. However, during the RT, only a few students solved the questions and uploaded their responses to EBA. Some teachers indicated that they did not use EBA resources because their students could not access them.

After MEB added a synchronous meeting tool to the EBA platform, teachers were encouraged to teach synchronous lessons. Synchronous lessons were conducted only by some of the public school teachers. Students’ access to the internet was often limited by the available internet connection of their parents’ connection. They either did not have sufficient internet connection to attend the synchronous lessons or did not have access to the internet during the day because their parents were working outside the home. Thus, students attended the synchronous lessons irregularly most of the time. Additionally, there was a drastic decrease in the lesson hours. Only one or two synchronous mathematics lessons were arranged weekly for the students in comparison to the 5–6 hours per week before the RT. Some teachers tried to look for additional options for extra lesson hours.

“Six lesson hours (including all lessons) per week were allowed for 5th graders in EBA, 1 hour per week for mathematics. This was not enough for me, at first this was a huge shortcoming for me. I taught 2 hours a week to 6th graders until June 19 [and] I took the initiative to solve questions for [extra] 1 hour myself and did it via Zoom apart from EBA.”

Monitoring and assessing students’ mathematics learning was difficult for the teachers. MEB announced that students’ grades in the 2019–2020 Fall semester were valid for the Spring semester. Teachers believed that it was unfair for the students who tried to do the tasks that teachers sent continuously and took responsibility for their own learning. These efforts were not reflected on students’ grades for the Spring semester. They also indicated that Fall semester grades might not indicate students’ performance in the Spring semester. Although they did not prefer this grading policy, there seemed to be no other option given the students’ lack of access to the learning resources. On the other hand, teachers could not make adequate assessment for students’ learning in their WA communication or synchronous lessons because they could not get responses from most of the students for the tasks they had assigned. They could not receive any response from the students for their questions during the synchronous lessons and could not observe how students were solving questions, which they would normally do in the classroom.

Public school teachers described the above processes as their individual actions most of the time. They rarely expressed collaboration with mathematics or other teachers in their schools, which they indicated as an important shortcoming. Likewise, they did not specifically indicate administrators’ support.

3.1.2. Private school teachers’ practices

Private school teachers’ practices were shaped by the decisions made by their mathematics departments and/or the school administration. They worked with the other mathematics teachers in their schools and even in the other schools in the same school group. There seemed to be an effective collaboration among the teachers in the mathematics departments: “*Everyone was responsible for certain lessons, that person prepared those lessons. Sometimes it didn’t go as planned. We called the teacher who prepared that lesson right away, we helped each other.*” These schools had personnel for information technology maintenance to support the teachers.

Private schools had already been using learning management systems (such Google Classroom and Moodle platforms). They did not employ EBA-related resources and they required teachers to produce materials and videos for the students: “*We prepared power point presentations for each lesson. We tried to add animation to all of them. We gave daily life examples. We always tried to encourage children with quizzes and competitions.*” Some schools provided tablets and graphic tablets for the teachers and students.

Private schools started to organize synchronous lessons in the second week of the break and informed the teachers about the teaching schedule. While some schools reduced the lesson hours to two hours per week (compared to 5–6 hours) or lesson duration to 30 minutes (compared to 40 minutes), some schools continued with the exact face-to-face schedule during the RT. Students’ attendance in the synchronous lessons were monitored by the school administrators most of the time.

Teachers distributed the assignments via the learning management systems to the students and gathered them back in the same way. They also used WA to remind the students and parents about the assignments, and to respond to mathematics questions from individual students. However, many students did not submit their responses back or did not complete the tasks thoroughly:

“[7 of 21 students] followed and did homework. [Completed] assignments were fake. [Students] wrote several irrelevant operations under the assignment. I guess they thought that we did not check it. They [tried to make it] look as if they did [the homework].”

Although MEB’s decision about the Spring semester grades was valid for private schools, some schools organized examinations via the schools’ learning management systems to gather information about students’ learning. Even though the schools had far better materials and technological opportunities, teachers still had difficulty monitoring

students' learning during the synchronous lessons:

"I did not know what students were doing because I could not see them. I asked a question, [there was] no answer. That was the biggest problem. In addition, students were not turning on the cameras and microphones. Therefore, I felt like I was teaching the lesson to myself. I could not decide whether students understood [the content] or not."

3.1.3. Common efforts and concerns

Both public and private school teachers were concerned that students did not have access to the classroom environment and emphasized the limited or lack of learning-related communication with the students. Almost all teachers pointed out that important learning opportunities in the classroom environment were not present in RT and students who depended on these opportunities fell behind in their learning. For example, students were not able to ask questions to teachers immediately when they did not understand an issue. Similarly, those who were rather silent in the classroom were not able to ask questions to their peers as they did in the classroom. Teachers stated that lack of classroom interactions limited students' learning opportunities and were concerned that these students could not learn effectively: "*I think they could not ask us many questions [about the questions] they could not do. Normally, they were asking more questions at school.*"

Teachers were specifically concerned about to what extent students learned the new concepts. They mostly reported that students' learning was decreased when they started to teach the new topics, based on the assignments they could monitor. The reasons were different for the public and private school teachers. Public school teachers were not sure how effectively they explained the new concepts to the students in WA communication. They did not think that these concepts were effectively explained on EBA-TV either. They sometimes called the students who did not have internet access via their parents one-by-one to guide them in their learning by assigning tasks and explaining topics that they could not understand. Not being able to have effective communication with the teachers seemed to affect students' motivation to learn largely: "*In mathematics, it is not only about explaining, it appears that the classroom environment and the teacher make a big difference. I noticed this. I did not think that the children's motivation would decrease this much.*" Private school teachers, on the other hand, were not sure to what extent the students were following the synchronous lessons because they could not observe the students during these lessons. They realized that students were not motivated to participate in the lessons and tried to increase their interest in studying mathematics in different ways.

The case of the 8th grade students is worth mentioning here. MEB announced that the 8th graders, who would take the national examination to attend competitive high schools, were not responsible for the Spring semester content in the exam. Both public and private school teachers were concerned that this decision would result in a learning loss at the high school because students did not pay attention to important content (such as Pythagorean Theorem) for about a semester. Many public school teachers stated that especially 8th grade students who were preparing for the national examination were either stressed because they could not study effectively in the absence of the school and teachers, and the status of the examination was unclear; or discouraged from taking the examination: "*There were students who gave up their performance and effort [they used to have] at school.*"

3.2. Factors affecting mathematics learning loss

The above analyzes seemed to point the inequalities among the students and schools, and the lack of learning environment as the major reasons for learning loss. The analyzes also revealed that the mathematics teachers' practices, concerns, and efforts during the RT were interlinked with three major moderating factors for learning loss. The

"interlink" made it difficult to report these factors without certain repetitions of or references to the practices, efforts, and concerns. Hence, below, we document these moderating factors by re-visiting some findings we presented above to provide a comprehensive picture of mathematics learning loss.

3.2.1. Students' low participation and perceived difficulties

There seemed to be two major types of student participation in the RT. One was students' communication with the teacher via instant messaging in WA and the other was students' participation in the synchronous lessons. On the other hand, public school students were supposed to participate in RT by following EBA-TV broadcasts and studying EBA-internet resources, whereas private school students were supposed to study the learning materials in the schools' learning management systems.

Public school students mostly participated in the RT via WA both in a group and individually. WA messages allowed for a more economic use of the internet and provided the students with access to the content, materials, and the teachers when they had limited connection to access the resources in EBA and synchronous lessons. Although WA seemed to provide a two-way communication between the students and the teachers that EBA could not, it was a band-aid with many disadvantages. Most public students did not have smart phones and they tried to maintain this kind of participation via their parents' smartphones. Teachers stated that parents sometimes forgot to inform the students about the teachers' messages. Therefore, many students missed the assignments, could not complete them on time, or they discontinued their communication with the teachers after a while.

Very few students participated in synchronous lessons in public schools. It was often the case that students were asked which synchronous lessons they would attend due to their limited internet access and only some chose mathematics. Yet, the numbers were low even when 2–3 classes of students from the same grade level were supposed to join the same synchronous lesson. In some cases, there were no students in synchronous lessons or the students who attended the synchronous lessons were not the same ones each time.

"One student said, "My internet [plan] will run out and I won't be able to [attend the synchronous lesson] next week". Since the same students did not attend all the time, they could not follow the lesson. There was only one student who was constantly following [the lesson]. Seventh graders did not attend any lesson."

Irregular attendance was a problem for the teachers because they were not sure what attending students knew about the previous concepts in each synchronous lesson.

Teachers indicated that there were fewer questions from the students during the synchronous lessons. Shortly after the synchronous lessons began, MEB announced that the teachers must not ask students to turn on their cameras. This requirement, however, limited teachers' monitoring of student participation in the lessons. Teachers asked questions to specific students to check their participation, but they could not get responses most of the time: "*We did not receive any response from some students in the lessons. The same students responded to all the time. There was carelessness, disinterest [among the students].*" The private school teachers suspected that the students used excuses not to participate in the lessons: "*We wanted the microphone to be turned on from the beginning, but then the students started to say "my headphones are not working" to avoid questions. However, they have the means to [buy it].*"

3.2.2. Limited use of methods to teach mathematics

Teaching mathematics brought its own struggles for the teachers. Most of the teachers in the study stated difficulties with not being able to use the pedagogical approaches they used in the classrooms while teaching mathematics in the synchronous lessons. Some also stated that mathematics was not easy to teach remotely, especially compared to

other content areas, such as social sciences. Although teachers tried to teach mathematics content by employing several tools and strategies, there were difficulties when they wanted to explain new topics, complex calculations, and geometry concepts to the students: *“The last subjects were prisms and volume. It was difficult when 3D got involved.”* When they wanted to show complex calculations to the students, they first had to set up the technological tools to make it possible:

“We could not do the calculations on the computer, it was very difficult. I did the operations using a pen on my mobile phone [...] I bought a tripod, prepared notes. I taught focusing on the paper by the phone.”

Teachers stated that mathematics could be taught remotely somewhat effectively when there were the ideal conditions, such as essential technological tools, teachers’ knowledge and skills for RT, students’ strong prerequisite knowledge and motivation, and smaller class sizes. Therefore, it was not possible for them to teach effectively under the available circumstances.

Many teachers compared their face-to-face mathematics teaching practices to their practices in the synchronous lessons. This comparison indicated that they prioritized classroom interaction for students’ learning because it enabled teachers to monitor and assess students’ learning, and to establish a friendly classroom environment. However, the lack of effective interaction during the RT affected their teaching methods and students’ learning of mathematics.

Not being able to see how students completed the tasks was a drawback in their RT practices: *“We cannot determine how students did calculations or what kind of strategies they followed in remote teaching; they only said they did them. But we could see it when we were walking around the classroom.”* Teachers could not see students’ facial expressions, which they used extensively to monitor students’ learning in the classroom because they were not allowed to ask students to turn on their cameras: *“It is more difficult for mathematics; it was not productive at all. We needed to understand from [the students’] faces whether they understood [the content] or not, but we could not see.”* It was also the case that students did not communicate their mathematics practices effectively: *“Remote teaching was very difficult. The student was doing something, but he/she could not explain how he/she did it. Otherwise [in the classroom], if you go next to him/her, there will be a different communication.”* Teachers seemed to realize that they relied on the affordances of the classroom environment and face-to-face interaction with the students while teaching mathematics, which they were not fully aware of before. They indicated that the lack of such an environment affected both their and students’ motivation, and students’ learning.

The lack of interaction combined with the technological limitations seemed to affect teachers’ pedagogical approaches in synchronous lessons. They could not employ more interactive approaches because students acted passively by turning off their microphones and not asking or answering questions. Approaches they used to motivate students in the classroom did not work either:

“I like to go next to the students in the lessons, to get excited about the lesson with them, and to [teach] lesson by having fun. But in this process, it was difficult to do such things in remote teaching. I made jokes in synchronous lessons, I got into a ridiculous situation when students’ microphones were turned off. So, I started to be more serious.”

3.2.3. Family SES and lack of collaboration

Public and private school students had drastically different family SES as described by the teachers. While private school students had access to essential technological resources and study environments, public school students did not have them. Some public school teachers mentioned the parents who lost their jobs during the pandemic and were primarily concerned about feeding the family.

Many public school teachers indicated that students did not have a computer and an internet connection, and most of their learning was through the content sent via the parents’ smartphones. The small number of students who had computers had limited internet connection, which was not enough to continuously attend the synchronous lessons. Parents’ smartphones also had the same problem. Additionally, there were other siblings at home who needed to follow synchronous lessons or access the content that teachers sent via the parents’ smartphones. There was not an effective study environment at home for public school students because they did not have their own room.

“Normally, students did not have their study environment, now I don’t think they had the study environment when all the children were at home. Because they have many siblings. There are 8–10 siblings, it is not possible. 95% of them live in the house with a stove, so all the children were in the room with the stove when the weather was cold.”

Public school students were with their siblings during the synchronous lessons most of the time. There was often a background noise during the lessons from the siblings and parents did not seem to provide a better study environment: *“While a student was attending the synchronous lesson, [there were] voices from behind, people come in and out of the room. those people were unaware that he/she was in the lesson. Parents did not care.”* On the other hand, private school teachers complained that although the students had all the resources, there were students who attended the synchronous lessons from the living room where family members were present.

Many teachers from both school types indicated that there were several indifferent parents who did not contact the teachers despite the teachers’ attempts to contact them. They informed the parents mostly via WA groups about the lessons, tasks and expectations from the students, distributed the assignments through these groups, and asked for their collaboration. However, they rarely received any response in public schools: *“Parents never reached us. I wrote to the parents, this lesson will be at this time, I sent the program. There were no responses. They never wrote.”* This situation was almost the same in some of the private schools:

“We told the parents that the student did not do his/her homework, we said that he/she did not attend the synchronous lessons, [but] they were not interested at all. [...] At first, we always informed the parents, but we did not get any response.”

Teachers commented on the parents’ lack of interest in students’ studies. They accepted the limitations due to the lack of resources in low SES families. However, they insisted that the parents should have monitored students’ work on the tasks teachers had sent and encouraged students to study. Instead, parents often complained to the teachers that they could not handle their children and expected teachers to encourage them to study: *“The parents did not help us. In fact, they always complain and expect us to make students study. They have to make their children [study].”* There were cases where students could not attend the synchronous lessons because they could not organize their daily sleep schedules. Teachers complained that it was the parents’ responsibility to help their children maintain a study schedule in the absence of actual school attendance.

4. Discussion

Middle school mathematics teachers’ accounts indicated that the major reasons for mathematics learning loss among Turkish middle school students was the existing inequalities and students’ limited or lack of access to the teacher, learning environment, and learning materials. Although teachers developed practices to engage students in teaching and learning interaction, students’ participation, teaching methods, and family SES and involvement moderated the effects of the

inequalities and the access to the learning resources.

The existing inequalities had several interacting layers in which moderating factors were also in place. At the *education system and school level*, the learning opportunities for public and private school students were profoundly different. The private schools provided similar learning opportunities for their students as they were more organized and more resourceful. Public schools, on the other hand, lacked coordination and collaboration, and either could not provide equal opportunities to all students or were not able to contact all of them. The learning materials, resources, and the number of synchronous lessons provided in public schools were limited compared to the private schools. At a more systemic level, even EBA resources were inaccessible to many students.

These extreme differences between the public and private schools created inequality in terms of provided learning opportunities for students during the RT. Although public school teachers tried to reduce the effect of this inequality in their efforts during the RT, this specific inequality had already existed in the Turkish education system before the pandemic (TEDMEM, 2020).

At the *classroom level*, the students in private schools had similar learning materials and opportunities. They participated in the synchronous lessons and had access to the schools' learning management systems. On the other hand, not all public school students in the same classroom had similar access to the teacher and/or the learning opportunities such as WA communications, synchronous lessons, and EBA resources. Therefore, a variation in learning loss among the public school students in the same classroom could be expected (Middleton, 2020). Fall 2020 semester started as face-to-face teaching with this variation and continued with further school closures shortly after, which most likely increased the variation.

Not being in a school environment seemed to be one important reason for mathematics learning loss for students from any type of school (Andrew et al., 2020). Neither private nor public school students had access to the classroom environment and the mathematics learning opportunities it provided as a result of addressing the mathematics content through different approaches, peer interaction, teachers' continuous formative assessment, teacher and student questioning, and discussion (Hiebert and Grouws, 2007). Both teachers and students were inexperienced in interacting in the synchronous lessons. Therefore, even when students had access to the technological tools and the internet, they could not have the learning opportunities they had in the classrooms. Although public school teachers employed WA to provide students with learning opportunities, the mathematical content, knowledge, and skills that teachers could cover in the WA communication were limited.

Home learning environment became more important when students were away from the school (Andrew et al., 2020; Sabates et al., 2021). At the *home learning environment level*, private school students had adequate physical environment to facilitate their learning that public school students did not have. These two groups of students, on the other hand, seemed to have similar low parent interest and support despite the drastic differences between families' SES. Lack of parent interest resulted in not attending to the synchronous lessons and not working on the assigned tasks at the RT progressed. This seemed to increase the learning loss especially for the students from disadvantaged families as an additional factor (Andrew et al., 2020; Tomasik et al., 2020).

At the *student level*, effective self-regulation skills and motivation to study, and familiarity with online learning tools seemed important for learning mathematics with less disruption during the RT. There were students who were able to regulate their study routines better and there were those who needed guidance and teacher presence for their studies. Private school students were generally familiar with learning management systems and online resources when the RT started. Therefore, it could be assumed that learning loss during the RT for self-disciplined students and for those who were familiar with online learning tools could be less. Still, the lack of motivation among the students was a major problem for all teachers, which resulted in a lack of participation

in the learning activities as expressed by teachers in earlier studies (Alper, 2020; Özdoğan and Berkant, 2020).

Our findings showed that teachers were not the only reason for and not the only solution of mathematics learning loss during the RT. There were multiple interrelated factors affecting students' access to the learning opportunities in complex ways. Turkey mostly continued with the RT during the 2020–2021 academic year. Despite the improvement in online resources and the number of synchronous lessons for public schools, the inequalities at many levels and the moderating factors revealed in this study still existed, and so did learning loss. School- and classroom-level inequalities will remain as long as the education system will continue to provide enhanced learning opportunities only for those who can afford them. Additionally, it is reasonable to assume that home learning support and student-level reasons for the learning loss were not improved much. Therefore, it can be concluded that the pandemic increased the effect of the existing inequalities on learning loss for students in Turkish public schools. In the words of one of our participants, students in public schools who were from disadvantages homes “*lost the only [learning] opportunity, the school.*” Additionally, students in both school types who benefitted more from the classroom environment did not have access to this environment for one more year. Hence, it should not be assumed that private school students did not have any mathematics learning loss.

The findings of the study were limited to the 28 public and private middle school mathematics teachers, their school contexts, and their verbal descriptions of the communication with the students and remote observations they had (or could not have) of the students they taught. Findings were also limited to the teachers' self-reported and perceived experiences, and to the interview questions. We did not observe teachers' RT and support practices, students' participation and difficulties, and students' home learning environment. We also did not interview with the students about their perceived RT experiences and learning loss. Yet, the study captured a snapshot of what RT practices took place in different school settings, what affected teaching and learning during the RT, and how these resulted in mathematics learning loss for the students in the participants' schools.

The students will be taught in the following years under the same curriculum despite the variations in learning loss caused by the cumulative effect of nearly 1.5 years of school closures. Teachers will have to deal with the curriculum pace and learning loss simultaneously. Students may still have learning loss despite the compensation period organized by MEB at schools before the 2021–2022 academic year (Kaffenberger, 2021; Kaffenberger and Pritchett, 2021). The study revealed that there were several interlinked factors influencing teachers' practices and students' mathematics learning loss during the school closures and that teachers were well-aware of these factors. However, it is important that decision makers are aware of these factors thoroughly and adjust the focus of teaching and learning at schools as compensating for the learning loss, not as maintaining the curriculum pace. Therefore, the findings of the study serves the decision makers with a set of research-based information to consider when they decide educational policies in the following years. Further research should focus on how teachers tried to compensate for the mathematics learning loss when schools reopen and what difficulties they experience. They should also concentrate on the students' point of view and the short and long term effects of the mathematics learning loss on their future mathematics learning.

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Ethics approval

Ethical guidelines of the Finnish National Board on Research

Integrity and Turkish universities were followed at all phases of the study.

CRedit authorship contribution statement

All authors contributed to the study conceptualization, methodology, data collection, data analysis, and the original draft. All authors read and approved the final manuscript.

Consent to participate

The data included the responses from the participants who consented to participate in the study. They consented that the anonymous data they provided would be used for research and publication purposes.

Consent for publication

All authors have consented for the publication of the manuscript.

Declarations of interest

None.

Availability of data and material

The data are not available due to the participant consent.

Appendix. Interview Questions

1. Can you explain the process that you and your students have been through since the beginning of remote teaching?
 - a. How did you try to continue your teaching?
 - b. How did you monitor your students' learning?
2. What kind of problems (technological, administrative, parent-related, student-related) have you encountered during the remote teaching process?
3. What kind of solutions have you tried for the problems you encountered?
4. What, if any, are the positive sides of this remote teaching process for you and your students?
5. Has remote teaching resulted in inequity among your students? How?
6. What do you think about the use of the previous semester's grades in student evaluations?
7. How do you think the next academic year will be if the pandemic continues?
 - a. What kind of difficulties do you think you will face?
8. Is there anything else you want to mention?

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