Distance Mathematics Teaching During the Pandemic – Experiences from Secondary Schools in Romania

Teo-Christian Ion(✉) and Elvira Popescu

Computers and Information Technology Department, University of Craiova, Craiova, Romania
ion.teo.n3d@student.ucv.ro, elvira.popescu@edu.ucv.ro

Abstract. Over the course of almost two years, in 2020 and also in 2021, the Romanian educational system was constrained by the restrictions arising due to pandemic's negative effects at the national level, to temporarily sustain the entire instructional process in the online environment, in the form of virtual or distance courses. Thus, mathematics teachers had to limit themselves to the use of existing real-time communication systems, which are not designed specifically for mathematics teaching, but for general use (e.g.: video-conference, virtual classes). The purpose of this study is to highlight the experience that both secondary school students and teachers had while holding mathematics classes in the virtual environment, thus marking the advantages and disadvantages of the used systems and software, compared to teaching in face-to-face settings. The data were collected by means of surveys and interviews applied to students and teachers respectively. The paper also includes proposals on how online educational systems for teaching mathematics should be designed, so that they resemble, as much as possible, the traditional teaching approach.

Keywords: Mathematics education · Distance learning · Distance teaching · Virtual learning environment · Secondary schools

1 Introduction

The start of the pandemic crisis in March 2020 revolutionized the way in which the activity of the pre-university education system was carried out, by requiring the application of some critical, spontaneous measures. In Romania, teachers and students were faced with an unexpected challenge, namely that of continuing to hold classes without being physically present. Because of the restrictions, the educational system was forced to quickly respond to these challenges, by implementing, testing and using new distance learning and teaching methods, through existing communication systems [1]. Distance education or online education can be defined as an effective way of teaching and learning, which can be used any time, regardless of location, allowing participants to access educational materials in electronic format or to integrate different technologies in the instructional process [2, 3].

M. Milrad et al. (Eds.): MIS4TEL 2023, LNNS 764, pp. 179–188, 2023.
https://doi.org/10.1007/978-3-031-41226-4_19

Based on existing research, we can conclude that online learning environments are bringing, in many cases, a higher level of efficiency compared to traditional learning environments. However, studies show that this is not true for *mathematics education*, regardless of whether it is about primary, secondary, high school or university level [4]. Overall, online education has not only managed to present technical disadvantages, but also social ones, pushing young students towards anxiety, stress, insecurity and isolation [5]. Therefore, even if all disciplines of study were affected by the sudden and unexpected transition to distance education, it could be easily observed that mathematics was much more affected than others [6]. For example, Xu and Jaggars [7] show that it is more difficult for students to achieve performance in mathematics by using existing online teaching systems, compared to traditional teaching. Aldon [8] presents the results of a survey which targeted several groups of high school students from Germany, France, Israel and Italy, based on which we can determine the main problems faced by math teachers, in terms of on-line teaching process: the difficulty of monitoring the students' activity; the absence of a large number of specific facilities for math lessons; the lack of stable internet connections and devices which facilitate the teaching and learning of mathematics; the need for the simultaneous use of several platforms or applications.

Drijvers [9] noted that most teachers opted to use general-purpose educational applications, which are not specifically designed for teaching mathematics. In general, both synchronous and asynchronous communication tools were used [10], although in some situations, for various reasons, teachers opted only for the use of asynchronous systems, such as e-mail, media sharing platforms or social media platforms [11]. Nadeak [12], while studying the effectiveness of using social media platforms in the educational process, concludes that these platforms could produce the expected results only in case of teaching theoretical courses. Drijvers [9] proposes that every teacher and every student use drawing tablets, especially during mathematics lessons, and also use platforms or applications for sending images, for edits and annotations, for correcting and checking individual work; in addition, the creation of an actual class is necessary, which shows up each virtual student to the teacher, on a display, for an easier monitoring. Dubey and Pandey [13] believe, however, that the current education system does not have an adequate technical infrastructure to adapt to such a situation. The different environments and social conditions in which students and teachers live are the reason why they cannot have access to the same technical facilities (devices, internet connection, etc.).

The main purpose of the current paper is to identify the difficulties that both teachers and students faced in online mathematics classes during the pandemic, in a Romanian secondary school context, and to propose solutions or alternative systems which should eliminate or diminish the observed shortcomings. The rest of the paper is structured as follows: Sect. 2 introduces a survey that was applied to students and reports the findings on three main directions (educational platforms and personal logistics, effectiveness of the online teaching approach, ideal platform for distance mathematics education). Next, Sect. 3 presents the results of interviews conducted with math teachers, summarizing their experience with the online education approach. Finally, Sect. 4 provides some conclusions and outlines our proposal for building a comprehensive virtual system for teaching mathematics, which aims to resemble as much as possible the traditional teaching process.

2 Student Survey

2.1 Description of the Questionnaire

Our goal was to create an overview regarding the current situation and to be able to note the main differences or shortcomings of the virtual systems used in distance mathematics teaching compared to traditional teaching (i.e., face-to-face teaching). Therefore, we used a quantitative approach, by creating a survey addressed to secondary school students, which aims to collect essential information about mathematics teaching in the virtual environment, during the two years of pandemic restrictions.

In order to obtain the most accurate results, the questionnaires were distributed to secondary school students of all ages, grades 5–8 in the Romanian educational system. The data were collected both offline (through printed questionnaires) and online (using Google Forms service), between June and December 2022. A total of 203 students from 5 secondary schools in Romania filled in the survey.

The survey was made up of 17 items, including both multiple-choice and open-ended questions. Three main categories of items can be distinguished, namely:

1. *Items related to personal logistic elements, from a technological point of view, including the web platforms or software applications used* – this section aimed to identify the platforms used by the teachers (and implicitly by the students) for real-time communication (i.e., giving virtual lectures in video-conference format), for the sharing of materials and homework and for grading, and also the type of devices used by the students to access these facilities, and the internet connection type.
2. *Items related to how the instructional process unfolded* – the purpose of this section was to provide data that could be used to analyze the effectiveness of the software systems used, in the process of distance mathematics teaching. The questions referred to: teacher-student interaction, virtual whiteboard, students' notebooks, solving and sharing homework (worksheets), solving, submitting and evaluating assessment tests, access to other types of resources (textbooks, problem books etc.). Also, this category of items included two questions which allowed students to provide comments regarding the advantages or disadvantages of the aforementioned systems.
3. *Items with proposals regarding the features that a platform dedicated to math teaching should include* – this section aimed to extract students' opinion regarding the desirable features of a system of distance teaching and learning for mathematics. This section also contained an open-ended question which allowed the students to give their personal ideas on the topic.

The main results of the survey are summarized in the next three subsections.

2.2 Findings Regarding Educational Platforms and Personal Logistics

According to the survey data, it was found that in most cases (about 48%) teachers opted to use Google Meet[1] platform for delivering the lectures. Another sizeable part of

[1] https://meet.google.com/.

teachers (46%) chose to use Zoom[2] platform, while the rest chose Microsoft Teams[3] or Cisco Webex[4] platforms.

Regarding Internet access, about 85% of the participants had access to a broadband internet connection, while 15% of them had to use mobile data. However, even if a large part of the students were able to use a wired internet connection, their comments reveal that many of them were dissatisfied with the quality of the connection, having to deal during lessons with *"lags and interruptions", "lack of signal", "non-functionality of the platforms", "jerky sound", "blurred images"*.

When it comes to communication with the teacher outside of the classes, the majority of the math teachers (about 60%) opted to use Google Classroom[5] as a system for submitting homework, assessments and for distributing specific documents or announcements. At the same time, about 43% of the teachers opted to use the instant messaging network WhatsApp[6] exclusively or in addition to Google Classroom.

2.3 Findings Regarding the Effectiveness of the Online Teaching Approach

Based on the survey responses, it can be concluded that the existing systems did not meet the students' needs with satisfactory features for teaching and learning mathematics at distance, as follows:

1. *From a technical point of view* (i.e., platforms, features, access to textbooks, blackboard, notebooks, interaction with peers and teacher), about 70% of respondents believe that online math classes unfolded worse or much worse than face-to-face classes.
2. *Teacher-student interaction in the virtual environment* is also an important issue. Approximately 65% of students believe that the teacher-student interaction was worse or much worse during online classes compared to the interaction during face-to-face classes, thus the transition to the virtual environment was deeply affected.
3. *The process of submitting and marking the evaluation tests* has also been impacted. The mathematics discipline is heavily dependent on the way of writing mathematical expressions (called "mathematical language") and on the way of drawing geometric shapes. However, the basic features provided by the generic communication platforms employed (for example, the option to upload documents, or the option to fill in a text field), do not support writing algebraic expressions or drawing geometric figures; alternatively, in some cases they require the knowledge of a specific math-expressions focused language (such as LaTeX), which is deemed too complex for the secondary school students. Therefore, the solution proposed in most cases was for the students to solve the exercises on paper, to scan them and then send them to the teachers. Thus, the instructors could not monitor the activity of the students during the assessment tests, and also found it difficult to mark and annotate the scanned documents. Overall, 70% of students believe that the process of submitting and marking evaluation tests

[2] https://zoom.us/.
[3] https://www.microsoft.com/en-us/microsoft-teams/group-chat-software/.
[4] https://www.webex.com/.
[5] https://edu.google.com/workspace-for-education/classroom/.
[6] https://www.whatsapp.com/.

in the virtual environment was worse or much worse compared to the face-to-face environment.

4. *Similarly, the process of submitting and checking the homework assignments or the individual worksheets during the classes*, was deemed to unfold in a worse or much worse manner in the online environment by 65% of the respondents. This is because the teacher was not able to directly monitor the students' work, but had to request students to send photos of their notebooks or worksheets in order to be able to check them.

Moreover, about 60% of the students had greater or much greater difficulties in understanding the concepts taught in math classes in the virtual environment compared to the traditional face-to-face settings.

2.4 Findings Regarding an Ideal Platform for Distance Mathematics Education

The last part of the questionnaire suggested several features that an ideal distance teaching and learning system for mathematics should possess, asking students' opinions about them. In addition, students could also add their own ideas or proposals, based on the experience of taking math classes in a virtual environment over the course of almost two years. The following features were proposed:

1. *Tool for writing mathematical expressions and drawing geometric shapes, along with a virtual whiteboard and a personal virtual notebook*. More than 90% of respondents believe that an ideal system for distance mathematics teaching and learning should include an easy-to-use mathematical writing feature (for mathematical expressions), together with a way to draw geometric shapes in order to cover the field of geometry as well. In addition, a virtual whiteboard system should be included, on which both the teacher and the students could write during the mathematics classes. A virtual notebook would also be welcome, so that students no longer need to use their own physical notebooks and the teacher can constantly monitor their activity.
2. *Tool for managing homework, worksheets and evaluation tests.* Approximately 94% of students consider it is useful or very useful for a distance mathematics teaching and learning system to include support for online homework, worksheets and assessment tests, based on the mathematical writing tool presented above. Thus, students no longer have to scan their own physical notebooks / worksheets, and the teacher can easily monitor and mark their work.
3. *Virtual library*. More than 85% of respondents consider that it is useful or very useful for a distance math teaching and learning system to include a virtual library from which students could easily access the textbooks and additional resources distributed by the teacher.

Moreover, over 95% of respondents consider it useful or very useful that the proposed features should be integrated in a single, all-encompassing software application.

3 Teacher Interviews

In order to draw a more comprehensive picture of the online educational experience during the pandemic restrictions, we performed a series of interviews with mathematics teachers in addition to the survey applied to the students. The interviews were conducted by phone and involved a total number of 10 mathematics teachers from secondary schools in Romania. The goal was to obtain essential information about the teachers' experience: the ways or techniques to teach classes in the virtual environment, the approach for giving evaluation tests and grading them, the solution for monitoring the individual activities of the students, the features and shortcomings of the platforms used and the impact of the online education experience on students.

After centralizing the opinions of the interview participants, it was found that most of the teachers consider that the distance mathematics teaching has a different specific, compared to other disciplines. In particular, in mathematics classes, both the teacher and the students use the mathematical language, which has its own symbols that are not found on the usual keyboards of the devices that the students possess.

"Mathematics is not a typical discipline of study. Moreover, it contains two main branches, namely Algebra and Geometry, which differ greatly in terms of writing. Algebra has different mathematical expressions, with specific symbols. Geometry has, in addition to the specific language, also the geometric shapes that each student should be able to draw individually." (T1)

"In other disciplines it is not absolutely necessary to check the students' solutions by looking into their notebooks. You can simply have them read the essay, homework and so on. When it comes to mathematics, checking the students' notebooks is mandatory." (T2)

"Mathematics is different. You can't do math using a simple keyboard or mobile phone. You can't ask students to learn LaTeX. It's very complex and, anyway, it takes a long time to write in such a language. In geometry the situation was tragic because many students had either mobile phones or laptops without a mouse." (T3)

At the same time, the lack of drawing tablets, which would allow students and teachers to write mathematical expressions or draw geometric shapes, made it difficult to teach mathematics at a distance. Thus, teachers without such devices had to send scanned pictures to the students, and the other way around.

"We would send a picture to the class group, then the students would draw it on their notebooks and then send it back. This took a long time. Some failed to take pictures, others took them blurred, others made mistakes and had to start over. Images kept coming in and you didn't even know who sent them." (T4)

"I used the drawing tablet and it was easy for me, but the students found it difficult. They could see what I was writing, but they could not "go to the blackboard", they could not show what they did to others. I had to ask them for pictures. They would send them to me, I would verify them, and that's how the hour went." (T5)

"Verbal mathematics does not exist. It is difficult to dictate mathematical expressions, geometric figures... The drawing tablet was essential." (T6)

The absence of a comprehensive system, which includes in the same place several facilities such as taking assessment tests, real time virtual classes, submitting documents, solving worksheets, accessing virtual textbooks and so on, made the smooth running of classes a difficult process.

"We switched from one application to another continuously... I was using web forms, although you can't write mathematical expressions there. We used WhatsApp and other platforms like that to communicate or send documents. We got confused with them." (T8)

"When I sent them a link to an app where they could access a math game, they were taken out of the meet and I wouldn't see them again until they were done and get back." (T5)

"Phones were freezing, and also our PCs, because of having too many apps open." (T7)

Another problem was the lack of a stable internet connection and the need to use a mobile phone even though students had a computer or laptop.

"It is very important that all students could attend classes and have access to the same features. It is difficult to work on the phone, having such a small screen. Most of the students, if not all of those with whom I talked, had an older working computer at home, but they could not use it because the operating systems were no longer compatible with applications such as Google Meet, Zoom or others. They were forced to use mobile phones." (T1)

"Both the students and I had problems with the internet connection. When it was slower, you could no longer understand each other. Some used mobile data, and even though they had a connection, the speed was terrible." (T3)

"Some students did not participate online at all because they did not have access to a good internet connection. They tried one, two, three times and were unsuccessful. Unfortunately, they missed a lot and today they are still striving to recover missed contents." (T4)

Applying online evaluation tests was also difficult, as existing systems lack fraud prevention features.

"I would send the evaluation tests to the class group. Students transcribed them on paper and solved them. We were still connected on the platform, but that was useless because they could talk to each other or they could search for solutions on the internet. At the end they would take photos of the sheets and send them to me." (T1)

"Some were stalling. At the end of the test "their internet no longer functioned" and they could not submit their work." (T3)

"I used online forms, but this way the entire test contained only multiple-choice, matching and completion items. Students could not elaborate their answers anymore. Today we easily identify this shortcoming as they really do not know how to write solutions and explanations." (T2)

However, despite the negative aspects identified above, when it comes to giving the lectures in the virtual environment, by using video-conferencing platforms, the teachers observed that the students were much more open and attentive during the classes.

"I liked it. The students were much more attentive. By not being present in a classroom, they were no longer distracted by others, but focused on the lecture. If we hadn't had the other limitations, I think we would have been better off than with face-to-face classes." (T1)

"If I could, I would go online again. Technology attracts them, so even mathematics seemed more interesting to them." (T9)

"I thought it was very good. We got along great, we collaborated beautifully. We handled it well. I would like to continue giving the lectures online." (T10)

4 Discussion and Conclusion

The present study tried to identify and reveal the challenges and difficulties that students and teachers were facing, in terms of technical features to support mathematics classes, for secondary school, in an online environment. It can be easily ascertained that there is currently no solid alternative in terms of teaching mathematics, so that traditional lessons can be translated online, into a virtual environment. The lack of tools that could facilitate the writing of mathematical expressions and the creation of geometric shapes thus becomes a main obstacle in the entire process of supporting distance mathematics classes. In addition, the impossibility of accessing essential technological facilities, such as a stable, high-speed internet connection or the use of devices that satisfy the minimum requirements of the existing platforms make the online education approach inaccessible for some students or teachers.

The study also has some limitations. First of all, the number of participants (students and teachers) is relatively small, hence the findings cannot be easily generalized. Secondly, the transition to online learning was made on a very short notice at the beginning of the pandemic, with limited technical support for both students and teachers. In addition, participants lacked previous exposure to online learning environments, which further hampered their overall experience.

Based on the findings of the survey and interviews, we propose the creation of a system for distance teaching and learning for mathematics, which would try to resemble as much as possible the traditional teaching process and to eliminate the shortcomings presented above. The platform would broadly include the following features:

1. implementation of a single, comprehensive application that includes all the necessary features for distance teaching and learning of mathematics, so that they can be found in the same place

2. implementation of an algebraic writing tool, using an intuitive natural language approach, so that both the teacher and the students can use it for writing mathematical documents
3. implementation of a mechanism for drawing geometric shapes, similar – as far as possible – to making drawings on paper, using virtual geometric tools such as ruler, protractor and compass, so that students do not lose this important element of geometry
4. implementation of a virtual whiteboard and virtual notebooks, so that each student can have their own notebook and the teacher can check it at any time, thus eliminating the need to scan it and send it
5. implementation of a virtual library, which includes textbooks and collections of mathematical problems, in an easy-to-access format, which the teacher can recommend to the students
6. implementation of a module to support online virtual lectures, which provides access to the algebraic writing tool and the geometric shapes drawing tool described above, as well as easy access to problems recorded in the virtual library database; thus the teacher can automatically select, retrieve and display problems and questions on the virtual whiteboard and the students can answer them, making solutions visible in real time
7. implementation of a module to support real-time evaluation tests, integrating the algebraic writing tool and the geometric shapes drawing tool, as well as mechanisms to identify and prevent fraud attempts
8. implementation of a module for automatic or manual generation of assessment tests, worksheets and homework, starting from the particular class topic and using the database provided by the virtual library mentioned above
9. implementation of a module for performing homework, which would integrate, apart from the algebraic and geometric support tools, the personal virtual notebook of each student, that the teacher can easily visualize and mark accordingly
10. implementation of a learning analytics system, which should be integrated with all the modules presented above, and should include statistical data related to the students' performance in class (e.g., based on attendance, problem solving speed etc.), on the assessment tests, homework, worksheets (e.g., based on the number of correct answers, the time spent on the tasks etc.) and on the reading of the recommended materials from the virtual library. This should also include a module for automatic detection of individual or class-level knowledge gaps and misconceptions
11. integration of a complex real-time communication system that should be supported by both modern and older devices, which should also require as little bandwidth as possible in terms of users' internet connection.

To sum up, the paper provided an overview of students' and teachers' experience with distance mathematics learning during the pandemic, in a secondary school context. Starting from these findings, an outline for a comprehensive online educational system for teaching mathematics is also proposed. We are currently working on designing and implementing such a platform, which aims to address the existing challenges identified by the students and teachers.

References

1. Hung, R., Wati, U.A.: 'Digital home schooling' during the pandemic: possibilities and challenges. Knowl. Cult. **8**(2), 36–43 (2020)
2. Yamamoto, G.T., Altun, D.: The Coronavirus and the rising of online education. J. Univ. Res. **3**(1), 25–34 (2020)
3. Blaschke, L.M., Bedenlier, S.: Online learning. In: Blaschke, L.M., Bedenlier, S. (eds.) Oxford Research Encyclopedia of Education. Oxford University Press (2020)
4. Ferguson, S.: Attrition in online and face-to-face calculus and precalculus courses: a comparative analysis. J. Educators Online **17**(1) (2020). https://www.thejeo.com/archive/2020_17_1/ferguson
5. Pelaez, M., Novak, G.: Returning to school: separation problems and anxiety in the age of pandemics. Behav. Anal. Pract. **13**(3), 521–526 (2020)
6. Locke, V., Patarapichayatham, C., Lewis, S.: Learning Loss in Reading and Math in US Schools Due to the COVID-19 Pandemic. Istation, Dallas, TX (2021)
7. Xu, D., Jaggars, S.: Performance gaps between online and face-to-face courses: differences across types of students and academic subject areas. J. High. Educ. **85**(5), 633–659 (2014)
8. Aldon, G.: L'enseignement des maths pendant le confinement en Allemagne, France, Israël et Italie. MathémaTICE 72 (2020)
9. Drijvers, P.: Math@ distance: distance mathematics teaching during Covid-19 lockdown. https://www.nationalacademies.org/event/07-09-2020/math-distance-distance-mathematics-teaching-during-covid-19-lockdown (2020)
10. Martin, F., Polly, D., Ritzhaupt, A.: Bichronous online learning: Blending asynchronous and synchronous online learning. Educause Review (2020)
11. Barlovits, S., Jablonski, S., Lázaro, C., Ludwig, M., Recio, T.: Teaching from a distance—Math lessons during COVID-19 in Germany and Spain. Educ. Sci. **11**(8), 406 (2021)
12. Nadeak, B.: The effectiveness of distance learning using social media during the pandemic period of Covid-19: a case in Universitas Kristen Indonesia. Int. J. Adv. Sci. Technol. **29**(7), 1764–1772 (2020)
13. Dubey, P., Pandey, D.: Distance learning in higher education during pandemic: challenges and opportunities. Int. J. Indian Psychol. **8**(2), 43–46 (2020)