

Article

Teaching from a Distance—Math Lessons during COVID-19 in Germany and Spain

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Abstract: In 2020, Germany and Spain experienced lockdowns of their school systems. This resulted in a new challenge for learners and teachers: lessons moved from the classroom to the children's homes. Therefore, teachers had to set rules, implement procedures and make didactical–methodical decisions regarding how to handle this new situation. In this paper, we focus on the roles of mathematics teachers in Germany and Spain. The article first describes how mathematics lessons were conducted using distance learning. Second, problems encountered throughout this process were examined. Third, teachers drew conclusions from their mathematics teaching experiences during distance learning. To address these research interests, a questionnaire was answered by $N = 248$ teachers ($N_1 = 171$ German teachers; $N_2 = 77$ Spanish teachers). Resulting from a mixed methods approach, differences between the countries can be observed, e.g., German teachers conducted more lessons asynchronously. In contrast, Spanish teachers used synchronous teaching more frequently, but still regard the lack of personal contact as a main challenge. Finally, for both countries, the digitization of mathematics lessons seems to have been normalized by the pandemic.

Keywords: distance learning; mathematics education; COVID-19 pandemic; digitization; synchronous teaching



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1. Introduction

1.1. Emergency Remote Teaching in Germany and Spain

In the spring of 2020, the COVID-19 pandemic forced massive and abrupt changes upon schools: instead of learning together in the classroom, students and teachers were suddenly spatially separated. Thus, the COVID-19 pandemic has raised new challenges and demands regarding teaching and learning [1,2], which “on a global scale have shocked teachers at all levels and at the same time inspired them to find solutions to problems they have not encountered before” [3] (p. 456).

This unforeseen and unprepared phase of distance education is often characterized as emergency remote teaching (ERT) [4–8]. It is caused by “a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances” [4] (pp. 1–13), i.e., to quickly set up temporary solutions for maintaining and enabling teaching despite spatial distance. Due to the urgency of shifting lessons to an online format, the term “panic-gogy” is also used to describe the situation both teachers and learners found themselves in during the spring of 2020 [9,10].

On the other hand, teachers all over the world reorganized their teaching methods rapidly and—mainly by means of digital media and the internet [11]—found solutions to tackle upcoming problems [3,12] and created a new form of continuity in education [13]. In this paper, we aim to compare the teaching practices employed during the ERT phase and those of the subsequent phase, the “new normal” [14], post-ERT phase, using Germany

and Spain as examples. Therefore, two methods of teaching are relevant: synchronous and asynchronous teaching formats.

Due to the COVID-19 pandemic, the place of learning shifted from the classroom to the children's homes. Thus, following the Johansen space–time matrix [15], students were no longer educated in the same place at a common time but were located in multiple places. Concerning the time of learning, distance teaching could be organized in a synchronous or asynchronous setting. While synchronous learning formats, e.g., video conferencing and chat/instant messaging, enable direct teacher–student interactions, asynchronous formats, such as emails or learning videos, do not require the real-time participation of teachers and learners [16]. In the context of this paper, we define “synchronous” teaching as a setting in which teachers and students come together at the same time whilst still being spatially separated. “Asynchronous” teaching, on the other hand, describes a setting in which teachers provide learning materials that students complete in their own time, i.e., remotely after receiving them.

The paper addresses how teachers in Germany and Spain transformed their math lessons during the ERT phase and how they consolidated their methods of teaching in the post-ERT phase. Furthermore, the paper examines the teachers' conclusions drawn from their distance learning experiences caused by the COVID-19 pandemic.

1.1.1. ERT in Germany 2020/2021

In Germany, all educational institutions from kindergartens to universities closed for the first time in March 2020. Starting mid-May, eight weeks after the closing, German schools reopened for students in their final year. Other students, apart from regional variations, were taught following a partial attendance model until the end of the 2019/2020 school year.

It was only after the summer vacation that all German states returned to regular in-person classes. In December 2021, a second national school lockdown was enjoined by the German government due to the state of the pandemic. Until February 2021, with regional differences, students from grades one to six and exam classes were taught fully in-person or using a partial attendance model. However, due to regional infection rates, the school lockdown was maintained for older students in most German counties until June 2021.

1.1.2. ERT in Spain 2020/2021

In Spain, students stayed at home and were educated remotely from March 2020 until the end of the 2019/2020 school year. During the 2020/2021 academic year, the educational setting differed regionally. In regions such as Cantabria, students from the kindergarten to university level were educated using a face-to-face model accompanied by special measures, e.g., classes were divided into groups taught by different teachers.

In other regions, for example, in Madrid, in-person and partial attendance models were implemented: while kindergarten offered face-to-face supervision, students at schools and universities received a combination of in-person and online lectures.

1.2. Theoretical Framework

In order to analyze ERT as a special form of teaching from a teacher-oriented perspective, the TPACK model [17] can be used. This framework aims at describing and understanding the teaching process. It is based on the pedagogical content knowledge model by [18] and adds a technological domain since “new technologies have changed the nature of the classroom or have the potential to do so” [17] (p. 1023).

Thus, the TPACK model comprises three components of teachers' knowledge (see Figure 1): first, content knowledge is related to the teacher's subject and includes topics which are taught and learned at school. Second, pedagogical knowledge can be characterized as teachers' knowledge about practices and methods of teaching and learning as

well as about the process of learning. Third, technological knowledge is aimed at the use of technological tools and standard resources [19].

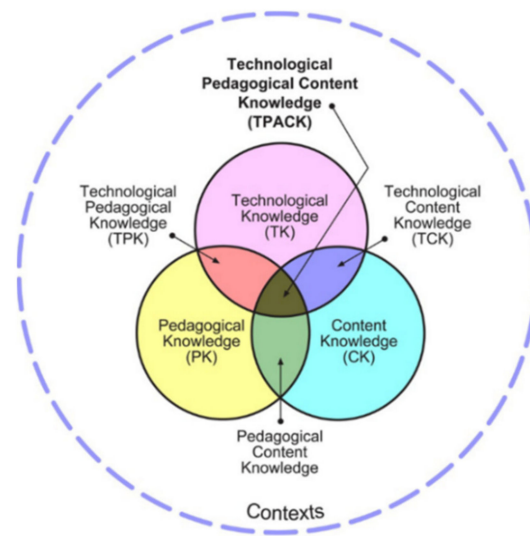


Figure 1. The TPACK framework according to [19] (p. 63).

The TPACK approach focuses on the relations in between. The core of the model, the intersection of all three components, is the technological pedagogical content knowledge. It is considered to be “the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies” [17] (p. 1029).

1.3. State of the Art

1.3.1. Data on the ERT Situation in Germany

In Germany, the communication in the ERT phase during the first school closure was mainly asynchronous via email or cloud systems. Synchronous elements, such as video conference tools, were used rarely [20–22]. The learning time per day decreased from 7.4 to 3.6 h on average. In particular, the learning time of under-achieving students decreased in comparison to high-performing students [22].

Concerning the teachers’ perspectives, two-thirds of the 1031 teachers surveyed stated that their schools were technically not or poorly prepared for distance learning. Moreover, 69% saw the need to increase their own technical competences [21]. Further, teachers named the creation and delivery of digital lesson content, the communication with students and a lack of digital equipment for students as challenges [21]. Since the access and ownership of digital devices is strongly linked to parental income [23], a so-called digital divide [24] has been feared.

Nearly two-thirds of the students received at least weekly feedback on their worked-on tasks [20]. However, both parents [22,25] and students [26] wished for more synchronous communication and feedback in spring 2020.

Both aspects, the receipt of feedback and the quota of synchronous learning settings increased in the beginning of 2021: three out of four students received weekly feedback from their teacher, and again, three out of four students were taught in a synchronous setting [27]. Even though the time spent learning at home increased, it was still far lower than that spent face-to-face-learning in school (4.3 vs. 7.4 h) [27].

1.3.2. Data on the ERT Situation in Spain

In Spain, the vast majority of Spanish students have access to the technical conditions required to participate in online distance lessons. However, the access possibilities and the number of hours spent on school-related work are related to the income of the parents: students from families with a higher income have more access to internet-enabled devices

and spend more time on learning activities during the school lockdown [28]. Thus, a digital divide can also be observed in Spain [6,29].

In spring 2020, nearly 60% of the teachers reported that they had a rather or totally adequate level of digital competence to handle the distance education by means of digital media [28]. Furthermore, broad teacher training opportunities and an increased confidence by teachers in using digital media was reported [6]. In addition, 75% of the teachers reported that they were able to help all students in an appropriate way [28], and 81% stated that they are very or quite satisfied with their teaching [28].

On the other hand, two out of three teachers declared the adaption of their teaching to ERT as quite or very difficult [30]. Furthermore, the vast majority of Spanish teachers agreed that they felt overwhelmed (77%) and more stressed (68%) [28]. This supports the assumption that the development of new teaching strategies is the main issue for digital teaching and learning at home [31].

Regarding the availability of ready-to-use material, Spanish teachers stated that at least half of the used tasks were self-created [30]. This can be seen as an indicator that the availability of appropriate material was not given. In addition, a broad majority reported that the number of tasks was reduced, and the pace of teaching was slowed down. As a result, the teachers had to soften their criteria for assessment [30].

1.3.3. Comparison of ERT in Germany and Spain

Both the German teacher survey of Forsa [21] and the Spanish teacher survey by Rodríguez-Muñiz et al. [30] investigate teacher–student communication during the ERT phase in spring 2020. The national results are compared in Table 1. Since the non-subject-specific survey of [21] separates teacher–student communication and the distribution of tasks related to the used medium, the higher percent value is considered in the comparison.

Table 1. Use of digital and non-digital media in Germany and Spain for ERT.

Use of Media in spring 2020	Germany Forsa [21]	Spain Rodríguez-Muñiz et al. [30]
Email	79%	73%
Online platforms	45% (Digital learning platform or digital working space) 31% (Website of the school)	64% (Platform for remote teaching) 51% (File storage platform incl. chat or video calling) 50% (File storage platforms)
Video conference tools	14%	44%
Social media and mobile messaging	28%	17% (Mobile messaging) 10% (Social networks) 9% (Blogs)
Paper copy via post, collection or distribution	33%	N/A
Telephone	46%	N/A

In both countries, email was the most reported medium of teacher–student communication. Besides deviations in the subdivision of the communication process, online platforms and, in particular, video conference tools, were reported more frequently in Spain than in Germany. Furthermore, every second Spanish teacher used online platforms for file storage (with or without synchronous elements).

The level of non-digital methods of communication in Germany is remarkably high: the use of paper copies—sent via post, collected by students and parents or distributed by teachers—was reported by one-third of the teachers. Nearly half of the teachers called the students or parents. Comparable results are not queried in the Spanish survey.

Overall, this comparison indicates that in Spain digital tools for teaching were implemented more rapidly than in Germany—even though the technical (computer access)

and social preconditions (appropriate working space and parental support) are comparable [32,33].

This finding is in line with the reports of the Organisation for Economic Co-operation and Development (OECD) [32,33]. Before ERT, online learning platforms were far more often applied in Spain than in Germany. Moreover, for Spain, a stronger trend towards the digitization of school can be assumed since Spanish teachers participate in online teacher trainings above the average level (46%; OECD average: 36%; *ibid.*) and consider ICT skills to be of great importance [34]. Even though similar data are not available for Germany, related studies indicate a relatively low rate of teacher trainings concerning digital competencies [35] and a significantly lower use of digital media [36] in an international comparison.

1.4. Research Question

For Germany and Spain, several challenges of distance learning were reported in the previous section. For both countries, the fear of an increased educational inequality is reported—either caused by unequal learning conditions due to the social status [27,28] or due to the so-called digital divide [24].

National differences can be seen in the implementation of teaching. Spanish teachers used more digital and, in particular, more synchronous methods of communication than German teachers (Table 1). Hereby, Spanish teachers perceive themselves as media-competent [30], while German teachers report a deficit in using digital tools [21].

Nevertheless, these results are at a general level, and it is difficult to draw a conclusion on a certain subject and its contents, namely, mathematics. For the post-ERT phase, i.e., the phase of consolidated distance learning, respectively, the return to face-to-face learning in view of the possible resumption of distance learning, a broader analysis of the conduct of mathematics education in Germany and Spain is currently missing. Since research on educational experiences in dealing with pandemic situations is urgently needed [37], we pose the following research questions.

RQ 1: How were mathematics lessons conducted during ERT?

RQ 2: Which problems did teachers identify with regard to mathematics lessons during ERT?

RQ 3: What are the current consequences of ERT for mathematics teaching and learning?

To answer the research questions, a teacher-centered perspective was chosen in order to refer back to the prior findings concerning the first lockdown phase. Hereby, German and Spanish teachers were first examined separately. Subsequently, the experiences of teachers in Germany and Spain during the COVID-19 pandemic were compared.

Concerning RQ 1, our study describes how mathematics distance learning was implemented. Therefore, the rate of synchronous math lessons and the used tools for assigning and discussion tasks in Germany and Spain are also compared with respect to the general finding of [21,30].

In RQ 2, the identified problems are limited to mathematics teaching during ERT. A comparison occurs at two levels—a nationwide comparison with general research findings and a comparison between Germany and Spain.

In RQ 3, a comparison of Germany and Spain should give an impression of teaching and learning mathematics in European countries during and hypothetically after ERT.

2. Methodology

In order to answer the research questions, a first data collection was carried out in November 2020 using an online questionnaire with $N_1 = 171$ German mathematics teachers. Therefore, the questionnaire was sent to German schools and the community of the MathCityMap users—a digital tool for outdoor mathematics. In spring 2021, the questionnaire was shared with Spanish teachers by means of the FESPM (a federation of Spanish teachers with 5000 participants) and the MathCityMap community, which resulted in $N_2 = 77$ answers from Spanish math teachers. Through the different survey dates, it is

important to observe, in particular, the answers of the Spanish teachers for the first ERT retrospectively. This change in perspective might change the impression due to a longer period in between the actual teaching and the survey.

In the questionnaire, the teachers indicated their school type on a voluntary basis. Furthermore, 120 of the 171 German participating teachers teach at secondary schools, 36 at integrated or cooperative comprehensive schools, 10 at vocational schools and 5 at primary schools. The majority of Spanish teachers educate at secondary level (69 of 77 teachers), one at primary level, three at vocational level and four at university level.

To identify problems and consequences of mathematics distance education during the COVID-19 pandemic, we considered all answers of primary, secondary, vocational and university mathematics teachers to be relevant. Therefore, the results are not limited to a specific student age, but only to the subject of mathematics.

2.1. The Questionnaire

The questionnaire contained a total of five closed and three open questions. Three closed questions related to [21], which investigated the used media (Items 1 and 2) and the encountered problems (I6) during the lockdown in spring 2020. To set the answer possibilities of the closed questions, the most frequently occurring free-text answers of [21] were provided in a multiple choice selection. The occurring challenges (I6) were further investigated with a free-text answer.

However, in the present study, these questions were directly linked to mathematics education. In addition to these items, we posed questions concerning the used criteria for selecting mathematical tasks (I3) and referred to the number of synchronous math lessons (I4 and I5). In question 8, the teachers were asked to reflect on their experiences during ERT and to assess the extent to which their mathematics teaching has changed as a result of distance learning. An overview of the questionnaire is presented in Table 2.

Table 2. The items of the questionnaire. Items related to Forsa [21] are marked.

Item	Question	Ref.
<i>RQ 1: Instruction</i>		
1	<i>During COVID-19-induced distance learning, how did you set math problems for your students?</i> ¹	x
2	<i>During COVID-19-induced distance learning, how did you discuss math problems with your students?</i> ¹	x
3	<i>What criteria did you use to select math problems for distance learning?</i> ²	
4	<i>At an early time of the COVID-19-induced distance learning, how often did you conduct your math lessons synchronously (together at a fixed time) with your school class?</i> ³	
5	<i>At this point in time (or at the end of the COVID-19-induced distance learning, if it is over), how often did you conduct your math lessons synchronously (together at a fixed time) with your school class?</i> ³	
<i>RQ 2: Problems</i>		
6	<i>What problems did you identify during COVID-19-related distance learning?</i> ¹	x
7	<i>Please explain the problems encountered in this process.</i> ²	x
<i>Problems concerning the organisation of teaching content</i>		
8	<i>Based on your previous reflection on the COVID-19 pandemic, has your mathematics instruction changed as a result of distance learning? If so, to what extent?</i> ²	

¹ Answer format: multiple selection. ² Answer format: free text. ³ Answer format: single selection.

The questionnaire is partly based on the questionnaire that was used in a representative German study in spring 2020 [21], but with a specific focus on mathematics education.

The multiple selection items I1 and I2 were directly linked to Forsa [21], while in I6, the most frequently occurring free-text answers of [21] were provided as selection options. Question I7—as in [21]—was provided in an open question format to identify specific problems of mathematics distance education. Items I3, I4 and I5 were added by the authors to receive a more detailed impression of math lessons during ERT. Due to the later timing in comparison to [21], item I8 was added to identify changes in teachers' mathematical teaching due to COVID-19-induced distance education.

Overall, the questions related to [21] were modified and extended, especially with respect to the posed research questions on problems and consequences. In the sense of the mathematics teaching and the comparison of German and Spanish teachers, we used an explorative approach. To allow the comparison of both countries, we used the same questions for German and Spanish teachers.

Hereby, the questionnaire aimed to analyze teaching and learning under distance education circumstances with a special consideration of the role of digital media. Since a teacher-centered position was taken, the items could be anchored in the TPACK model (Figure 1).

The first two items aimed to identify which tools were used during ERT. They asked how mathematical tasks were assigned by teachers and—after working on the tasks—discussed in class. Since the teachers' decisions on which tools to use for teaching mathematics is dependent on technical, pedagogical and content aspects, both questions were related to TPACK. Teachers' pedagogical considerations were addressed within item I3, which asked for criteria for selecting math problems during distance education. As technical aspects move into the background in contrast to I1 and I2, the question is part of PCK.

Item 6 asked for problems encountered during the ERT phase. Following the survey of [21], a multiple selection was provided, e.g., problems of insufficient technical equipment (technical), maintaining student motivation (pedagogical) or the selection of suitable materials for distance learning (content). As the selection options thus cover the three different aspects of teacher knowledge according to [17,19], I6 can be classified as TPACK-related. Finally, based on their previous reflection in ERT, the teachers were asked in I8 to assess whether, and if so, to which extent their mathematics teaching has changed. Therefore, we observed a relation to the TPACK section.

Items I4, I5 and I7 were not directly linked to the TPACK framework. Items I4 and I5 asked for a quantitative estimation of the extent of synchronous mathematics teaching during the ERT and a post-ERT phase, but not for its justification concerning technical-, pedagogical- or content-related aspects. Since the free-text question I7 aimed to identify problems during COVID-19-induced distance teaching and thus opened a wide scope for teachers' responses, the answers were not necessarily relatable to TPACK.

2.2. The Data Analysis

To analyze both the answers from closed and open questions appropriately, a mixed methods approach was chosen. According to [38], the combination of qualitative and quantitative results can, on the one hand, provide an overview of the general teaching methods and used tools—also with regard to the comparison of the two countries involved. Additionally, it is possible to integrate the results into the state of the art by relating the quantitative results with earlier, more general and nation-specific research findings.

On the other hand, the qualitative analysis of the free-text answers provided the opportunity to identify new categories, e.g., criteria and problems which might not have been identified by previous research findings. In addition, it was possible to underline the comparison of the countries in more detail as the free-text answers presented the individually chosen focus of the teachers' reports without any preselection. They were analyzed by means of qualitative content analysis [39], whereby the procedure was conducted in two ways—inductive and deductive.

In the results section, both parts of the mixed methods approach are presented with a quantitative overview at the beginning and, if available, a following qualitative analysis.

3. Results

The results section starts with the implementation of mathematics lessons and criteria for mathematics tasks, followed by the identified problems and finally focuses on the consequences drawn from mathematics teaching.

3.1. Implementation of Mathematics Lessons

3.1.1. Use of Tools and Media

To analyze the implementation of mathematics lessons during the COVID-19 school closures, teachers were asked about the assignment and discussion of mathematics tasks (multiple answers allowed). No information about the frequency of use was obtained, but only the statement whether the teachers used a certain tool/medium or not. The percentage in Figure 2 states the number of teachers for Germany (blue) and Spain (grey) who reported to have used a certain tool or medium during ERT. In this context, we understand the video conference, learning platforms with synchronous elements (e.g., chat), social media and messenger services and telephone as “synchronous” teaching tools and media. The other items are defined as “asynchronous” learning tools and media.

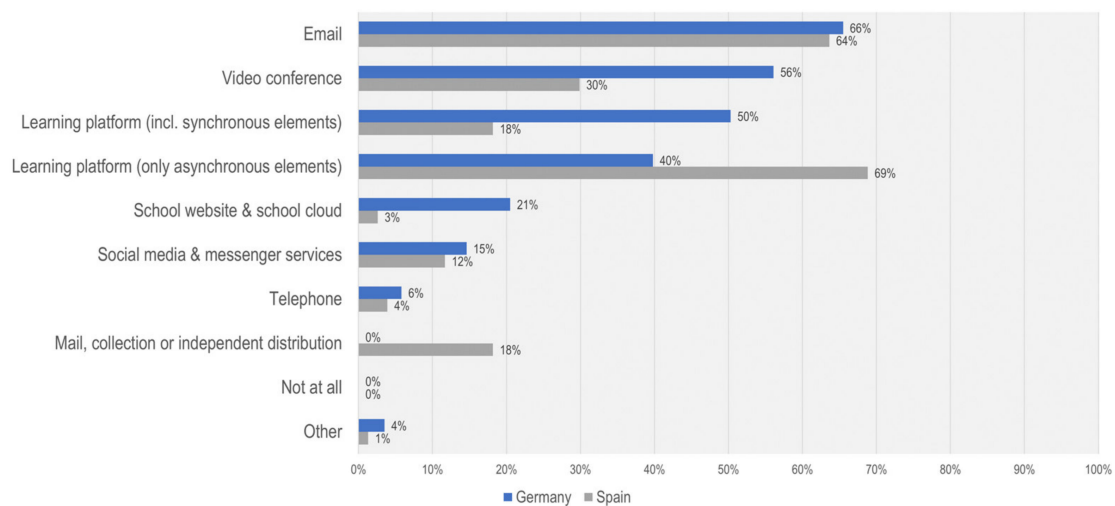


Figure 2. Task assignment in Germany and Spain (number of teachers who used certain tool in percentage).

In both countries, the task assignment (Figure 2) was performed via e-mail. Additionally, in Germany, video conferences and learning platforms with synchronous elements, e.g., chat, were also used by many teachers. In contrast, 69% of the Spanish teachers primarily reported the use of asynchronous learning platforms.

In the discussion of the tasks (Figure 3), the use of asynchronous tools was reported by less teachers in comparison to the task assignment. Video conferences as a synchronous tool were used by two-thirds of the German teachers during ERT. In Spain, even 82% of the teachers reported that they used video conferences for the discussion of tasks with the class. This is a significant increase in comparison to the assignment of tasks. Overall, in both countries, the shift from asynchronous to synchronous elements concerning the chosen tools for assigning and discussing tasks can be reported.

To examine the use of synchronous elements in more detail, in particular, in its frequency, we present the amount of synchronous teaching. The frequency of synchronous learning units used by German teachers during ERT in spring 2020 can be seen in Figure 4. While one-third of the German teachers were in direct contact with the learners several times a week or in every lesson, two-thirds of the learners were taught synchronously at most three times a month during distance learning, and 42% of them at most once a month or never.

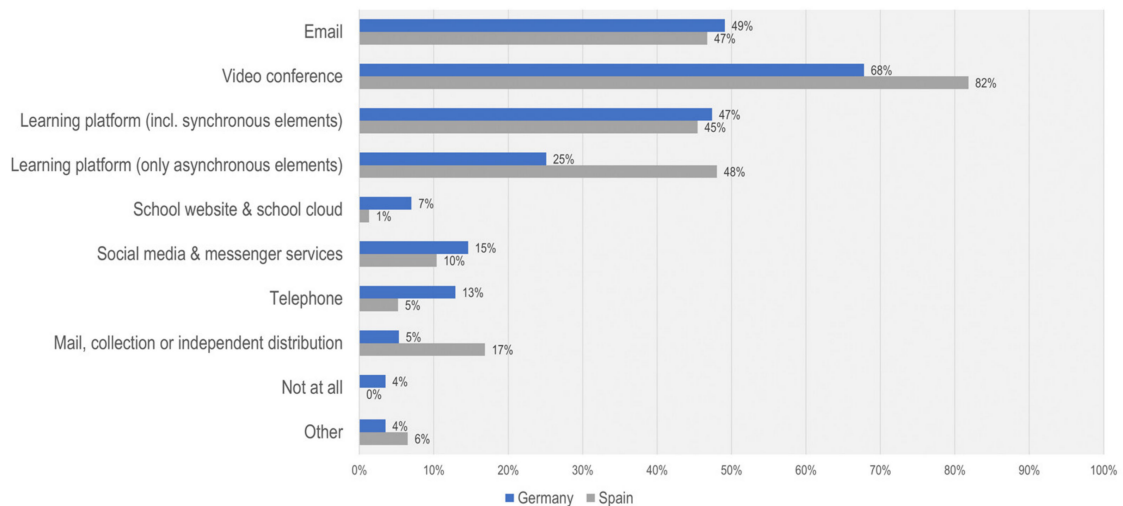


Figure 3. Task discussion in Germany and Spain (number of teachers who used certain tool in percentage).

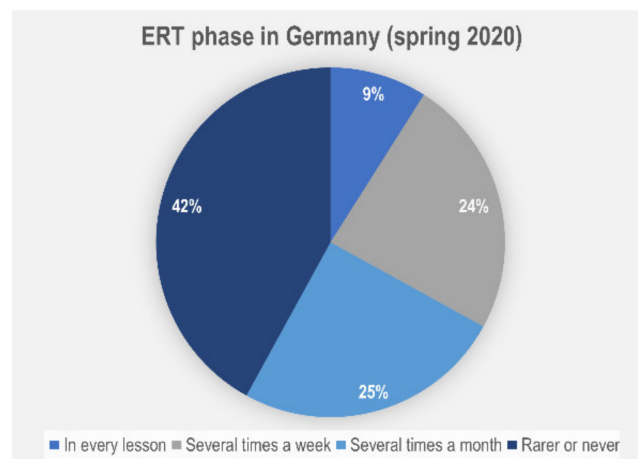


Figure 4. Frequency of synchronous teaching in Germany.

For Spain, we can distinguish the use of synchronous teaching tools for ERT in spring 2020 and the post-ERT phase in spring 2021. Both dates include the same sample since the teachers were asked to report retrospectively on their teaching in 2020. In the ERT phase, 31% of the Spanish teachers stated that they conducted synchronous teaching in every lesson. Together with 35% using synchronous teaching tools several times a week, two-thirds of the students experienced synchronous teaching regularly (Figure 5a).

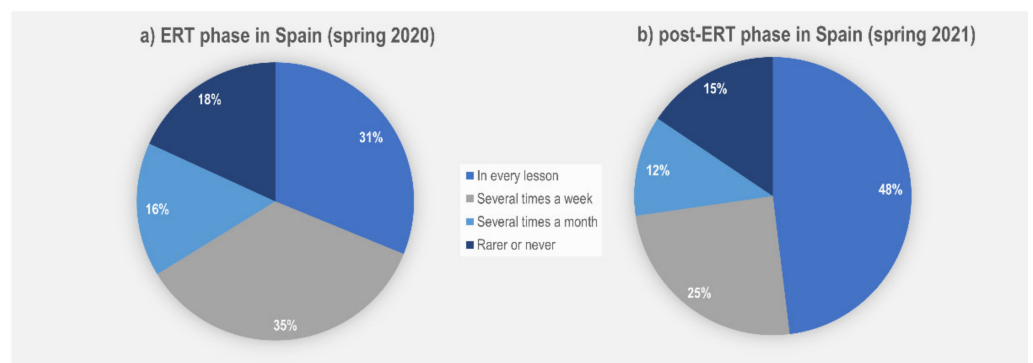


Figure 5. Frequency of synchronous teaching in Spain in spring 2020 (a) and spring 2021 (b).

A development during the year of distance learning and teaching can be observed when comparing the use of synchronous teaching in spring 2021 (Figure 5b). Even though the number of teachers who used synchronous teaching regularly was already higher during the beginning of ERT in comparison to Germany, the number still increased for the time of the survey. Nearly every second Spanish teacher claimed to use synchronous teaching tools in every lesson. With the additional 25% who stated that they used it several times a week, it can be assumed that more than three-fourths of the Spanish students experienced mathematics lessons synchronously at a regular level.

3.1.2. Criteria for Mathematics Tasks

Table 3 presents the criteria to select mathematics tasks during distance learning. In free-text answers, German teachers mainly named the thematic fit and the availability of contents (pragmatic criteria).

Table 3. Criteria for mathematics tasks in Germany and Spain.

Criteria	Example	GER N ₁ = 171	ESP N ₂ = 77
<i>Pragmatic criteria</i>			
Thematic fit with curriculum	<i>I have selected according to the curriculum from the textbook.</i>	13% (23)	29% (22)
Availability of material	<i>What tasks can learners access? e.g., the textbook that the learners had at home.</i>	5% (8)	0% (0)
<i>Didactic criteria</i>			
Reproduction and standard processes	<i>Tasks were mainly review tasks, i.e., care was taken to ensure that familiar task formats were involved.</i>	13% (23)	26% (20)
Comprehensibility and not too high level of difficulty	<i>The tasks had to be solvable for at least two thirds of the learners so that they did not throw in the towel.</i>	10% (17)	9% (7)
Diagnosis and individual support	<i>Simple “describe and explain” tasks so I can diagnose what was understood.</i>	7% (12)	1% (1)
<i>Problems concerning the organisation of teaching content</i>			
Self-control and hint option	<i>Use of the learning platform of a textbook publisher, as control and help functions were integrated there.</i>	12% (20)	6% (5)
Independent work	<i>It is essential that the assignments can be worked on independently, much more so than in face-to-face classes</i>	11% (18)	13% (10)
Independent acquisition and learning	<i>The tasks and the material had to be particularly suitable for independent learning.</i>	8% (14)	9% (7)

From a didactic perspective, in particular, the reduction in the difficulty level to the “minimum requirements” was emphasized: 23 German teachers (13%) stated that they mainly focus on tasks for repetition or calculation and schema-orientated tasks. This focus on “tasks for consolidation/repetition” seemed necessary due to the special relevance of independent practice and learning caused by the physical absence of the teacher: frequent reference was made to the possibility of autonomous processing, independent acquisition of knowledge as well as to the possibility of self-monitoring and learning support.

The Spanish teachers also highlighted the thematic fit of the taught topic through a focus on “the essential content for each level for the next course, trying to eliminate as little content as possible”. This assumption can be underlined by the high number of teachers (26%; 20 out of 77) who focused on tasks for repetition or standard procedures: “I selected those tasks that I considered to have the minimum necessary content so as not to suffer too great a deficiency for the following course”. Again, the teachers stated the need for independent and autonomous learning at home.

By comparing the criteria for mathematical task selection in Germany and Spain, first, the outstanding importance of curricular fit in both countries can be reported. Second, German as well as Spanish teachers reported a reduction in the mathematical level, which

is shown in the selection of repetition or standard tasks at a decreased level of difficulty. Third, in both countries, the teachers were aware of the higher demand of independent and autonomous learning and practicing. In contrast to Spain, the German teachers highlighted the possibilities of self-control or optional hints. Regarding the availability of materials and the use of tasks for diagnosis and individual support, two criteria occurring at a low level in Germany could be found in the Spanish survey.

3.2. Identified Problems

Figure 6 presents the identified problems for both German and Spanish teachers, whereby multiple selections were possible.

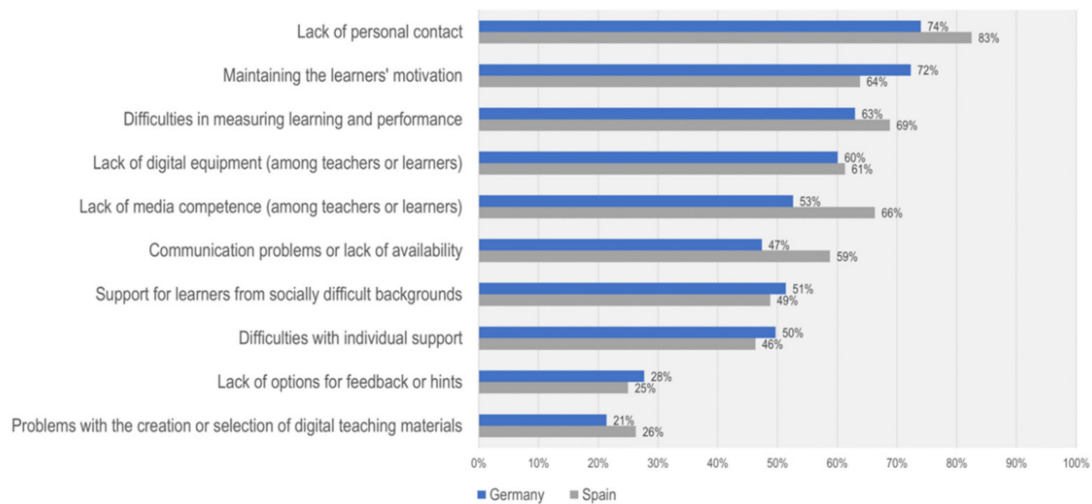


Figure 6. Identified problems in Germany and Spain (number of teachers who reported on certain problems in percentages).

The results in Germany show that all problems identified for general teaching [21] were perceived as relevant for mathematics teaching. About three-quarters of the mathematics teachers named the motivation of the learners as problematic. From the later free-text answers, it can be concluded that the teachers view this problem in connection with the lack of personal contact, for example, through the statement “Motivation without personal contact is difficult to maintain at a higher level”. However, despite spatial separation, only 28% of the teachers identified the lack of possibilities for feedback and hints as a problem.

At least half of the teachers named the support for students from socially difficult backgrounds and individual support as relevant problems during ERT in mathematics, as well as assessment and technical problems (lack of digital equipment or media competence). The interrelation of the problems can be seen in the free-text answers, e.g., assessment and motivation in “Due to the lack of grading and the long time at home, the feeling of a permanent holiday arose.”

The answers from the Spanish teachers showed a similar result concerning the relevance of the identified problems. As in Germany, the most frequently named problem by Spanish teachers is the lack of personal contact (83%), whereby it is even more often reported in Spain. Since Spanish teachers used synchronous teaching methods more frequently, two hypotheses can be drawn. Either the higher need for personal contact by Spanish teachers caused the more frequent use of synchronous tools or—since the video conference cannot replace learning at a common place—the use of synchronous methods further deepened the feeling of social isolation in contrast to in-person teaching.

In contrast to the German answers, especially the difficulties in measuring and learning, the lack of media competence and communication problems seemed to be more relevant problems in Spain, whereas the learners’ motivation was more often reported in Germany. Comparable to Germany, the lack of assessment tools was highlighted in 15 free-text answers as a major problem, also in terms of a loss of motivation and control: “A

very serious problem has been the lack of motivation of the students and the knowledge that they would pass the course in any case, without assessing the desired effort". Even though synchronous teaching was used more frequently in Spain, it seems that this method of distance learning cannot resolve the problems. Again, support for students from socially difficult backgrounds and individual support were mentioned as relevant problems of ERT in mathematics, whereas the creation of digital teaching materials and the lack of options for feedback and hints seemed to be a comparatively minor problem.

Six additional problems of distance learning can be identified from the free-text answers of the teachers (Table 4). While the given answers have already well depicted problems in the social and technical area, the category "Problems concerning the lesson's structure" needs to be added. The teachers referred, in particular, to the loss of control over individual or several pupils who "worked little, or copied it or did nothing", as well as to the increased time required for preparation, feedback and support. Furthermore, the teachers stated that online teaching requires an increased degree of self-organization from the students—also with regard to a lack of predetermined structure. In addition, especially the Spanish teachers reported that they were overloaded with the organization of the new and spontaneous teaching situation, i.e., due to a lack of didactic guidance and preparation. German teachers, in contrast, reported increased time consumption more frequently.

Table 4. Additionally identified problems from free-text answers in Germany and Spain.

Problems	Example	GER N ₁ = 171	ESP N ₂ = 77
<i>Social Problems</i>			
Unclear role of parents	<i>Parents sit behind the computer, tell the child what to do.</i>	18 (11%)	2 (3%)
<i>Problems concerning the lesson's structure</i>			
Loss of control and lack of discipline	<i>Some students are "lost".</i>	48 (28%)	7 (9%)
Lack of structure and self-organization	<i>Students drift out of the normal timetable—there is simply a different rhythm that is out of sync with the timetable.</i>	12 (7%)	4 (5%)
Lack of feedback to teachers	<i>I didn't know if students understood the material.</i>	7 (4%)	4 (5%)
<i>Problems concerning the organisation of teaching content</i>			
Increased time consumption	<i>Individual feedback took too much time. Going through the scanned solutions of each student and giving fair feedback became far too time-consuming.</i>	35 (20%)	4 (5%)
Lack of didactic guidance/preparation	<i>Hardly any didactic guidance for distance learning.</i>	8 (5%)	10 (13%)

3.3. Consequences

By analyzing the consequences of mathematics education during ERT in Germany, two trends emerged. On the one hand, about one-quarter of the teachers surveyed stated that their mathematics teaching has not changed in comparison to their pre-pandemic teaching since the resumption of regular teaching after the summer holidays 2020. On the other hand, half of the teachers mentioned a stronger integration of digital media. Therefore, especially the use of learning software and platforms, as well as a parallel digitalization of materials, was reported. Overall, the major tendency towards digital changes for mathematics teaching due to the COVID-19 pandemic in Germany can be confirmed by the survey. In the words of teacher, it can be assumed that teaching and learning mathematics "has become more digital—more teachers are now using digital media in face-to-face lessons as well". In contrast, and in view of one-fourth of teachers who have not shifted their teaching, an "enormous potential for innovation through distance or hybrid learning in Germany's schools" can still be seen.

In view of the Spanish teachers, three trends can be reported. While one-fourth of the teachers stated that their math lessons have not changed since spring 2020, more than half of the teachers reported an increased use of digital media in math lessons. These

teachers outline the major importance of learning platforms. A third minor trend, which can be reported for Spain, is the increased esteem for face-to-face learning. Caused by ERT, teachers showed a greater appreciation for common lessons in the classroom: “During the pandemic we have been forced to teach in other ways [. . .], but I consider that the face-to-face method, the traditional explanation [. . .] and the activities done by hand are better”.

Comparing the situations in Germany and in Spain (Table 5), the two main trends can be equally found in both countries. On the one hand, the teaching of one-fourth of the teachers surveyed has hardly changed. In contrast, more than every second teacher has increased their use of digital media. Thereby, in both countries, the increased importance of learning platforms and systems was named by 30% of the teachers, which are part of the digitalization group. Differences between the countries are the digitization of material in Germany and a higher esteem for face-to-face learning in Spain.

Table 5. Consequences drawn from distance learning.

Consequences	Example	GER N ₁ = 171	ESP N ₂ = 77
No chance of teaching	<i>No, my mathematics lesson has not changed.</i>	42 (25%)	19 (25%)
Increased importance of digital media	<i>The potentials of digital tools are becoming increasingly apparent in the form of truly expanded or new approaches to mathematics.</i>	90 (53%)	43 (56%)
Learning system/platform	<i>I upload my worksheets and whiteboard images to the learning platform and expect regular student submissions.</i>	27 ¹ (30%)	13 ² (30%)
Digitisation of material	<i>I have started to digitize all my material so that it can be made available digitally at any time.</i>	16 ¹ (18%)	2 ² (5%)
Esteem of face-to-face learning	<i>If there is no personal contact or physical classroom it is very difficult to advance in the learning and teaching of mathematics.</i>	6 (4%)	9 (12%)

¹ Number out of 90 German teachers stating an increased importance of digital media. ² Number out of 43 Spanish teachers stating an increased importance of digital media.

4. Discussion and Conclusions

From the procedures and problems during ERT, the research questions can be answered as follows.

RQ 1: How were mathematics lessons conducted during ERT?

For Germany, in view of the cross-curricular survey of [21], it can be confirmed that mathematics lessons were predominantly carried out asynchronously during ERT. Especially for the assignment of tasks, asynchronous digital tools were used. In Spain, the frequency of synchronous tools was used more regularly during the ERT phase in spring 2020 (reported retrospectively) and even more one year later. This confirms the general findings in [30] and especially the comparably higher use of video conferences in Spain for mathematics teaching. Regarding teaching, a distinction between the assignment and discussion of tasks can be observed for both countries, whereby it is remarkable that the Spanish teachers seemed to distinguish their choice of tools more significantly. Especially the use of asynchronous learning platforms for the assignment of tasks can be highlighted as a difference to Germany. This finding might have been caused by the fact that learning platforms had already been used more frequently in Spain before ERT [32,33].

ERT requires new criteria for the selection of tasks compared to face-to-face teaching, where tasks can be assigned and discussed directly. Teachers from both Germany and Spain named partially similar criteria for the choice of mathematics tasks during ERT, namely, the curricular fit; the reduction in difficulty levels, also due to a lack of technical equipment; and independent and autonomous learning possibilities. The German teachers also named the possibility of self-control and hints as well as possibilities for diagnosis and support as important criteria for their choices of material.

Statement 1: Even though synchronous learning formats were predominant in Spain, it can be seen that digital tools had to be used and that they were individually chosen for the assignment of tasks, on the one hand, and the discussion of the tasks, on the other hand. It can be assumed that this distinction—together with the use of digital tools—is a main difference in contrast to the normal face-to-face lessons. To compensate for this new situation, teachers set (new) criteria for their choice of mathematics tasks. Several criteria seemed to be relevant for normal teaching as well, but for many of them, it can be assumed that they were evoked by ERT. For example, the choice of easy or repetition tasks might have been caused by the mostly asynchronous assignment of tasks, which might make it harder to explain and clarify a new task format.

RQ 2: Which problems did teachers identify with regard to mathematics lessons during ERT?

From previous research findings, it was assumed that the new situation caused issues during distance learning and teaching. The problems of distance learning identified for general school teaching—mainly taken from [21] and related to [30]—can partly be confirmed for mathematics teaching. For example, the problems in the technical equipment, feedback, personal contact and assessment were reported for mathematics teaching. The Spanish teachers reported more problems at the communicative level, which is in accordance with [30]. It is interesting that the more frequent use of synchronous element in Spain did not obviously improve the communication situation. In addition, new challenges were categorized, in particular, at the level of lesson structure: loss of control and lack of discipline, e.g., through the lack of assessment, which has already been highlighted by [30], increased the expenditure of time (mainly in Germany) and the lack of didactical teaching (mainly in Spain).

Statement 2: Despite the higher frequency of synchronous teaching in Spain, it seems that most generally identified problems remain relevant. Although they were asked to report on their mathematics teaching, the teachers did not primarily focus on mathematics-specific problems with regard to contents and the curriculum. Since ERT only aims at providing “a temporary access to instruction and instructional supports [. . .] during an emergency or crisis” [4] (pp. 1–13), it addresses problems primarily concerning the general teaching and learning levels and puts content and subject-related problems in the background.

RQ 3: What are the current consequences of ERT for mathematics teaching and learning?

According to [5], a more frequent use of digital media in school in the post-ERT phase than before COVID-19 crises could be expected. Our survey can confirm this trend towards an increased digitization of math lessons in Germany and Spain. Nearly 50% of the teachers reported that they will use more digital tools in their regular teaching, i.e., through platforms or the digitization of material. The last aspect was predominately named by German teachers. However, in both countries, about one quarter of the teachers reported that they did not change their normal teaching after returning to school. In other words, while half of the teachers changed their teaching practice based on the experiences of the pandemic, around 25% of the teachers surveyed resumed their former, pre-COVID-19 method of teaching.

The Spanish teachers, in addition, drew another remarkable conclusion from ERT. They reported a higher appreciation of personal face-to-face teaching, which might have been caused by the lack of personal communication that many Spanish teachers reported.

Statement 3: ERT caused by the COVID-19 pandemic opened up the potential for a change—a disruptive change caused by a crisis. From the consequences that teachers drew, we assume that the rapid change of digitizing the educational system would not have taken place without ERT and the gained experiences.

The presented study aimed to provide insight into teachers’ experiences and problems as well as conclusions from COVID-19-induced distance learning. At the same time, the authors are aware of the following limitations. First, the relatively low number of Spanish

teachers should be taken into account during the analysis of the results and the comparison of both countries. Second, the choices of teachers—also through the community of a digital tool for mathematics education—might affect the representative nature of the results. Thus, the study cannot claim to be representative of German and Spanish teachers. Third, the questionnaire was modified from a representative German study [21] and extended by the authors in terms of the raised research question. Since [21] aimed to analyze how teachers handled the ERT phase in Germany, transferring the questions to Spanish teachers might not be appropriate for national specificities. Furthermore, due to the paper's focus on math education, the modification of the questionnaire and its extension in order to identify subject-specific problems and consequences might affect the validity of the questionnaires.

Nevertheless, the paper identified relevant criteria for mathematics tasks, such as individual control, availability of material, performance measurement, structure and feedback options, and the observed digitization trend motivates the development and use of digital tools that meet these needs for mathematics teaching. With reference to a strategy of “saving topics that are suitable for distance learning (e.g., geometry) for the next lockdown” and the reported evidence for a negative learning effect of COVID-19-induced distance education [40], this change can be profitable for both Germany and Spain.

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