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The COVID-19 Pandemic's Impact on 9th Grade Students' Mathematics Achievement

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Abstract: In this research, the influence of the Coronavirus disease (COVID-19) pandemic on 9th grade students' mathematics achievement is analyzed through quantitative and qualitative methods. A posttest only with control group design was used to compare the mathematics marks of 9th grade students from the previous school year (before the pandemic, control group) and the current school year (during the pandemic, experimental group). Seventy-three students from a public high school in Spain attending class on alternate days participated in the study. Three focus group sessions were held with students, and five semi-structured interviews were conducted—two with teachers and three with students' families. Results show statistically significant differences in students' mathematics achievement, with students enrolled in 9th grade the previous (pre-pandemic) year outscoring their peers currently enrolled in 9th grade (during the pandemic) by 22.17%. An overall negative effect size of Hedge's g = -1.11 was reported. Although significant statistical differences between groups were reported for both male and female students, the effect was 42.31% larger for male students (Hedge's g = -1.11) than for females (Hedge's g = -0.78). The qualitative information supported the quantitative results. Changes in educational settings, students' lack of motivation, monotony, and students' level of responsibility were qualitatively reported as factors that may explain this phenomenon. The main conclusion of this study is that the COVID-19 pandemic may be significantly and negatively affecting 9th grade students' mathematics achievement.

Keywords: *COVID-19, high-school, mathematics, Spain.*

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Introduction

The Coronavirus disease (COVID-19) has significantly altered the teaching and learning processes that routinely took place globally before the coronavirus pandemic (Aucejo et al., 2020; Toquero, 2020). Although research around the world has examined the psychological implications of school closures and online learning for students (Hasan & Bao, 2020; Islam et al., 2020; Kuhfeld et al., 2020; Wang & Zhao, 2020), the short- and long-term effects of the COVID-19 pandemic on students' achievement are still uncertain (Kaffenberger, 2021; Moliner, Alegre, et al., 2021; Sintema, 2020). When investigating these effects, several factors must be considered, as not only students but also teachers and principals have had to adapt to new teaching and learning situations resulting from pandemic restrictions with little to no advanced notice (Aliyyah et al., 2020; la Velle et al., 2020; Putri et al., 2020; Weiner et al., 2021). Students have had to cope with new educational settings due to hygienic measures that have included, among other accommodations, online learning combined with in-person learning (hybrid), groups of students attending school on alternate days, limitations on interactions and proximity among peers and between students and teachers, limited or no school trips, and limited access to digital and traditional classroom materials (Lee et al., 2021; Mohamad Nasri et al., 2020; Oyediran et al., 2020; Rahiem, 2021; Soares et al., 2020).

COVID-19 pandemic's influence on students' academic achievement

The literature examining the relationship between COVID-19 and students' academic achievement is still scarce, as studies on the effects of the pandemic on students' academic success have not yet been documented in depth. However, the latest studies in the field, most of which have been carried out in higher education, suggest that the pandemic may be negatively affecting students' achievement (Gonzalez et al., 2020; Moussa & Ali, 2021). Some authors consider the drop in student motivation and other psychological problems triggered by the severe pandemic restrictions as determinants

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of student achievement (Alemany-Arrebola et al., 2020; Alkhawaja et al., 2021; Carrillo & Flores, 2020). Others indicate that the sudden change to distance, remote, and online learning may be the reason for students' academic struggles during the pandemic, as most students were not used to these types of instruction (Aguilera-Hermida, 2020; Le et al., 2021; Shim & Lee, 2020; Yates et al., 2020). In any case, most authors suggest that student achievement may decrease considering the educational changes and the psychological factors associated with the pandemic that have impacted students (Al-Maroof et al., 2020; Almanthari et al., 2020; Rohman et al., 2020).

The Spanish Context

In Spain, the COVID-19 pandemic has significantly altered the educational organization of kindergartens, elementary and middle schools, high schools, universities, and all educational centers in the country. Friday, March 14, 2020, in Spanish school districts, immediately following the conclusion of the second term assessment, was the last day of in-person attendance at educational facilities at every learning level in the country for the remainder of the 2019–2020 school year (Di Domenico et al., 2021). Schools had to close and replace all in-person learning with distance learning until the following (2020–2021) school year (Palau et al., 2021) to limit the spread of the coronavirus. Therefore, during the third and last terms of the 2019–2020 school year (April, May, and June), students, teachers, principals, and all educational agents had to manage distance learning the best way they could (Han et al., 2020; Nieuwenhuis & Yerkes, 2021). This transition to online learning, implemented as a public health measure, was applied without prior notice, which put students and teachers in an awkward and unexpected situation (Koçoglu & Tekdal, 2020). These last three months of distance education constituted the first adaptation for both students and teachers (Drane et al., 2020). Online learning erupted as the most prominent option for many. Students who did not have access to digital tools or acceptable Internet speed were among those who struggled the most in this situation (Idoiaga Mondragon et al., 2021; Vladova et al., 2021). After the summer break, schools opened for the 2020–2021 school year with several restrictions. Most notably, students had to wear hygienic masks and maintain 1.5 meters distance from others inside the school at all times. Given the small area of many classrooms, this 1.5 meter restriction meant that the high schools could not accommodate all high school students in grades 7 to 12. To address the situation, priority for attending class in-person on a daily basis was given to students in grades 12, 7, 8, and 11, in this order. Many students in Spain enrolled in the 9th and 10th grades were divided into two groups within their high schools (Lavigne-Cerván et al., 2021): half of the students in a class attended on Monday, Wednesday, and Friday one week and on Tuesday and Thursday the following week, alternating days with the other half of the class. On the days students did not attend class in person, teachers could employ distance learning, online learning, or other ways of instruction for them (Ripoll et al., 2021; Santiago et al., 2021).

Aim of the Study

The main aim of this study was to determine if the COVID-19 pandemic has significantly influenced high school students' academic achievement in mathematics in Spain. High school students, especially those attending on alternate days for health protection purposes, may be most affected by this new situation. Not being able to attend class in the last trimester of the 2019–2020 school year and attending only half of the school days in person in the current school year makes them an intriguing stratus of research in the educational field. Therefore, in this study, we aim to determine if the COVID-19 pandemic has had a significant effect on students' mathematics achievement, and if it has, we aim to quantify the effect and investigate the factors that may explain the phenomenon.

Methodology

Ethics

This study was reviewed and approved by the research committee of the Valencian Ministry of Education through a research project with code number 20AQ65IN001. Students' parents or legal guardians also provided written informed consent to participate in this study.

Research Questions

Considering the research literature mentioned previously and the recent studies in the field, the following research questions were developed for this study:

RQ1: Has the COVID-19 pandemic significantly affected 9th grade students' mathematics achievement?

RQ2: Has the COVID-19 pandemic affected male and female students' mathematics achievement differently?

RQ3: If COVID-19 has significantly affected 9th grade students' mathematics achievement, what factors explain this impact?

Participants

Seventy-two academically above average students (23 male, 49 female) from a public high school in Spain participated in this study: 43 were in 9th grade in the 2020–2021 school year, and 29 were in 9th grade in 2019–2020. Their average age at the time of the research was 14.63 years old with a standard deviation of 0.87. The students all came from average socioeconomic backgrounds. Students were accessed through convenience sampling (Forgasz et al., 2018), that is, a non-probabilistic sampling method.

Design

A posttest only with control group design was used in this research (Lee et al., 2019). Students enrolled in 9th grade during the 2019–2020 school year served as the control group. These students attended the first two terms of the 2019–2020 school year (September to March) on a normal basis; the COVID-19 pandemic lockdown in Spain coincided with the start of the third term. Therefore, only their mathematics achievement for the first and second terms (before the start of the pandemic) was analyzed. Students enrolled in 9th grade in the current (2020–2021) school year—that is, those enrolled in 9th grade during the COVID-19 pandemic—served as the experimental group. Students in this last group attended school on alternate days in the first two terms of the current school year. The mathematics teacher recorded the daily lectures, uploaded them to YouTube Studio, and shared a private link via email with students so the content was immediately available to them on the days they did not attend class in person. They could watch the class live or view it later that day, as the session was recorded and permanently available to students. It was the students' responsibility to watch the lectures on YouTube on the days they did not attend school in person.

Classroom Procedures for Each Group

The same teacher that taught students in the control group in 2019–2020 taught students in the experimental group in 2020–2021. Students in the control group were taught on a normal basis. They took in-person mathematics classes four times per week. Traditional unidirectional instruction was combined with peer tutoring some weeks for this group (Moliner & Alegre, 2022). Students in the experimental group attended class on alternate days. Thus, each week, of the four mathematics lessons that would normally be presented to them in person, two were accessed via YouTube Studio (on the days the students stayed home and the other group attended in person). During the classes of the experimental group, traditional unidirectional instruction was employed. Students sat individually separated 1.5 meters due to social distancing measures.

Mathematics Content Taught

Students in both groups were taught the same mathematics content and took the same tests. Units 1 to 6 of the 9th grade mathematics course were covered in the first two terms, including the following content: Unit 1 – plane geometry (Thales theorem, Pythagoras theorem, blackbody locus, proportional triangles, planes of motion); Unit 2 – spatial geometry (polyhedrons, Euler theorem, calculation of surface area and volumes of prisms, pyramids, cylinders, cones, and spheres); Unit 3 – rational numbers (absolute and relative errors, operations and problem-solving with fractions and decimals); Unit 4 – powers and roots (powers and roots with rational numbers, operations with powers and roots, same base or same exponent and scientific notation); Unit 5 – polynomials (operations with polynomials, Ruffini's rule, notable identities, factorization through the residue theorem); and Unit 6 – equations (first and second degree equations, biquadratic equations, problem-solving through equations).

Instruments Used to Collect Information

The quantitative instruments used in this research were aimed at answering the first two research questions, while the qualitative instruments were intended to answer the third research question.

Quantitative instruments

Students' mathematics achievement was measured through individual written exams. Students in both the experimental and control groups took the same exams at the end of each unit during the first two terms of their respective school year. Each exam for the six units was graded from 0 to 10, and each student's average score for the six exams was used to represent their mathematics achievement. Each exam contained exercises and problems for the corresponding unit. Students were given approximately one hour to complete each of these exams.

Qualitative instruments

A semi-structured interview (Groothuijsen et al., 2020) was conducted with the public high school mathematics teacher who taught both the experimental and control groups. In this type of interview, researchers do not follow a strict list of formal questions; instead, they allow the conversation to flow and ask questions depending on the subjects' answers. Semi-structured interviews were also conducted with three students' families. The approximate duration of each interview was 20 minutes. Finally, three focus groups (Perines & Ion, 2020) were held with four students in each group.

Both students' families and students participating in the focus group were randomly selected from the experimental group of the study. The interview with the teacher and the student focus group sessions were held in person with the researchers. Focus groups were held in students' classrooms, and the teacher was interviewed outside the high school at a university research office. Interviews with the students' families were conducted by phone for health protection reasons.

Data Analysis

SPSS version 27 was used to perform all calculations for the quantitative data, that is, for the students' mathematics achievement variable. Means and standard deviations were reported using this software. Moreover, inferential statistics were carried out to compare the academic achievement between the experimental and control groups and also between males and females in the experimental and control groups. The student's t-test was used for these analyses (Amrhein et al., 2019). Effect sizes coming from these inferential tests were also reported; Hedge's g was used as a measure of effect size (Singh et al., 2021). A Kolmogorov-Smirnov test was carried out to ensure normality of the distribution ($Z = 1.11$, $p = .16$).

MAXQDA version 20.3 was used to analyze all qualitative data in the study, comprising all information from the focus groups and semi-structured interviews. Qualitative content analysis was employed (Parra et al., 2021). Information from the semi-structured interview with the teacher was coded as SI_T_1. Data from students' families were coded as SI_F_1 for the first family, SI_F_2 for the second family, and SI_F_3 for the third family. The data gleaned from the student focus groups were coded FG_X_Y, where "X" indicated the number of the focus group and "Y" the number of the student in that focus group. For example, FG_1_2 refers to student number 2 of the first focus group. Students' names reported in this research were invented for anonymity reasons. Code's reliability was ensured using the methods and suggestions provided by O'Connor and Joffe (2020).

Results

Quantitative Results

Descriptive results are shown in Table 1 for both the experimental and control groups by gender. As can be seen with the naked eye, the scores for the control group (before pandemic) were significantly higher than the scores for the experimental group (during pandemic) in all cases, that is, separately by gender and overall. An overall decrease of 22.17% was reported for students enrolled in 9th grade during the pandemic compared to the pre-pandemic 9th grade students.

Table 1. Descriptive Results by Groups and Overall

	Experimental group			**Control group**		
	M	**SD**	**n**	**M**	**SD**	**n**
Male	6.92	2.22	13	8.90	0.57	10
Female	6.67	2.70	30	8.53	1.61	19
Overall	6.74	2.54	43	8.66	1.34	29

Inferential tests between groups and effect sizes are reported in Table 2. Statistically significant differences were reported in all tests when comparing the experimental group and control group globally and separately by gender. The effect size for male students was 42.31% larger than for their female peers.

Table 2. Student's T-tests between Groups and Effect Sizes

Test	**Group A**	**Group B**	**t-test (sig.)**	**Effect size**
1	Experimental group scores	Control group scores	3.72* (p < .01)	g = -0.88
2	Female experimental group scores	Female control group scores	2.71* (p < .01)	g = -0.78
3	Male experimental group scores	Male control group scores	2.74* (p < .01)	g = -1.11

* p <. 05

Qualitative Results

Data from the semi-structured interview with the teacher pointed to certain factors that can be linked to the decrease in students' academic achievement in mathematics. SI_T_1 explained:

> *Many students have not adapted yet to attending on alternate days. They think that the days they don't come to high school are days for rest. It's not like that. You have to do your tasks, you have to study, you have to watch the online classes, you have to prepare for the exams you have next week, but they just don't understand.*

This teacher also referred to the students' low level of responsibility, as many did not watch their online classes. SI_T_1 further commented:

> *I'm giving them the opportunity to watch the classes online, just like if they were there with me. They can ask me questions through a chat… They can watch it hours or even days later because the whole class is recorded, and I don't mind if they watch it when it's better for them, but they just don't do it. I know because I have checked the statistics on how many students have watched my videos, and many times it's only a few of them. You also get them when you ask something that was in the online lesson, even if it is an easy content question. They can't follow the next class because they didn't watch the previous class. It's a disaster.*

During the interview, the teacher's fatigue, wear, and frustration due to the COVID-19 pandemic conditions were evident. He noted that his efforts to minimize the impact of the restrictions were not effective, as only a minority of students followed his online classes. He stated that he had seen a significant lack of motivation and a concerning monotony as the school year had advanced. As SI_T_1 indicated:

> *This situation is hard for them. Right now, they can't even train with their football teams, meet with their friends…. I'm not talking about partying on the weekend, but just certain outdoor or indoor activities that are healthy for them psychologically and physically. How am I supposed to motivate them? How are they going to be motivated? When I ask them what plans they have for the weekend, it's always the same—stay at home, play some video games, watch some series, Instagram…. This monotony is killing them and us.*

The teacher empathized with his students, understanding the apathy that they are showing this school year. In this context, he highlighted how the situation is generating anxiety and a lack of motivation among them.

The data from the semi-structured interviews conducted with students' families mentioned psychological factors, organizational educational changes, and students' level of responsibility as major issues. As SI_F_1 reported, *"I tell Ralph that summer is going to be different, that the situation will change and he will be able to go out with his friends and have fun, but right now it's very difficult to motivate him."* This statement illustrates that families are making an important effort to motivate their children, promising them a brighter future with more leisure activities.

SI_F_3 also referred to psychological factors:

> *Mary is a good student, and I know she will do fine with online classes. I know she watches them and is a responsible student, but lately she complains a lot. I can see she is fed up. Going out with her friends on the weekend was very important for her, and right now they are not allowed. It's very frustrating because I want to motivate her, but in this situation, there are few things that inspire her.*

SI_F_2 shared another perspective:

> *I work in the mornings, and I don't know if John has woken up by 11 in the morning. I call him when I have a break, I ask him what he is doing… but there's no way I can really control if he is studying or doing his tasks. This attendance on alternate days is awful for my son. I don't trust him much when he says he is doing mathematics or whatever.*

Families face a complex situation in trying to supervise their children and make sure they are following the online classes on the days they do not attend class in person. Most parents work during the day so they cannot control what their children are doing at home. This fact generates malaise for the families, as the parents do not have the tools to manage the situation.

The changes in educational settings due to the COVID-19 pandemic and the lack of motivation were also discussed during the student focus group sessions. FG_1_2 expressed the frustration that most students feel:

> *What's next? No mobile phone? We are not allowed to do anything. No matches, no training, no meeting friends… It's torture! I study because my parents are always annoying me with the study thing* [sic], *but I just don't feel like doing anything.*

Like everyone else, students' have been dealing with restrictions for almost one year, and they are tired. Friends are a cornerstone for adolescents, and the pandemic has cut down many relationships among them.

Like her peers, FG_3_3 indicated, "*We are all fed up. No parties, no going out, no Christmas…. We have lost what is supposed to be one of the best years of our life. It's horrible."* Students are aware that they are losing part of their youth, years very important for them when parties, social relationships, and friends play a vital role in their lives.

FG_2_3 admitted to not being responsible about watching the online classes:

> *I never watch them. If it's too early in the morning, I'm sleeping. If it's almost midday, I have to eat lunch because I'm hungry. As I have the chance to watch them when I want, I always say to myself that I'll watch it later, but I never watch them.*

As indicated by the teachers, students are not following the online classes and are acting more lazy than usual.

Discussion

Statistically significant differences were reported with medium to large effect sizes (Lortie-Forgues et al., 2021) between the experimental (pandemic) and control (non-pandemic) group, both overall and separately by gender. Hence, in response to RQ1, it seems the COVID-19 pandemic has had a significant effect on 9th grade students' mathematics achievement. As indicated in the introduction, the literature on this topic is still scarce, but some recent studies have already reported results analogous to the findings of this research. Although not specifically in the field of mathematics, the significant decrease in students' academic achievement during the COVID-19 pandemic has been also reported by Choi et al. (2020), Rahardjo and Pertiwi (2020), Al Salman et al. (2021), and Smith et al. (2021). Hence, the decrease in students' achievement found in this study is consistent with analogous studies in the field of education.

Regarding RQ2, although the mathematics achievement of both male and female students have decreased significantly, the COVID-19 pandemic seems to be affecting male students' mathematics achievement more than that of their female peers. The differences found in achievement levels between male and female students can be explained by females' higher perceived responsibility for learning in mathematics. The current educational context in which some Spanish students are learning (attending classes in person on alternate days with online learning) requires a higher level of responsibility from students. Thus, the less responsible students are expected to be more significantly impacted by the new educational structures. According to Armah et al. (2020), Lau et al. (2018), Los and Schweinle (2019), and van Putten et al. (2020), female students are often more responsible than their male peers in learning mathematics; this can explain why male students are experiencing an even higher decrease in their mathematics achievement than their female counterparts.

Finally, regarding RQ3 and considering the qualitative information in this study, the main factors that can explain the effect that COVID-19 has had on 9th grade students' mathematics achievement are changes in educational settings, students' lack of motivation, monotony, and students' level of responsibility. Several studies have addressed the psychological implications that the COVID-19 pandemic is having on students. As indicated by Garris and Fleck (2020), Bot (2021), Browning et al. (2021), Daniels et al. (2021), and Segarra and Julià (2022) several psychological factors, such as students' motivation, academic engagement, and perception of success, have decreased during the pandemic, while other factors, such as feelings of anxiety or cheating, have increased. According to these authors, each of these factors has a relationship with academic achievement. Therefore, it is logical that changes in the psychological variables mentioned previously and others not included in this research may be negatively affecting students' achievement (Moliner & Alegre, 2020; Moliner, Lorenzo-Valentin, et al. 2021; Zulherman et al., 2021). Hence, the qualitative information obtained in this research from students, teachers, and students' families is also consistent with previous studies in the field, as most research indicates that psychological factors play a major role, either directly or indirectly, in students' academic achievement.

Conclusions

The main conclusion that can be drawn from this research is that the COVID-19 pandemic may be having a significant and negative effect on 9th grade Spanish students' mathematics achievement. The magnitude of that effect may be medium to large. Organizational changes in the educational settings, lack of motivation outside school, monotony, and students' lack of responsibility may be factors that explain this phenomenon. Although this pandemic has significantly affected both male and female students' mathematics achievement, male students appear to be more affected by the situation, showing a significantly greater decrease in scores compared to their female peers. The higher perceived responsibility and ability to adapt to new learning environments that previous studies have attributed to female students compared to their male counterparts may explain this difference.

Recommendations

Although the outcomes of this research may seem strong, and they were supported with both quantitative and qualitative information, readers must bear in mind the very important limitations in this study. These limitations are addressed in the following section. Further research is needed to address the real impact of the COVID-19 pandemic on students' mathematics achievement in a more experimental and global way. Moreover, this is an immediate study that reflects the short-term effects of COVID-19 on mathematics education. The long-time effects of this pandemic in education are still uncertain. Hence, it is recommended to carry out future research to assess the long term effects of COVID-19 on students' academic success.

Limitations

Although the results reported for this study are significant and strong conclusions may be drawn from them, caution is required when interpreting the results and conclusions, as several important limitations in this research may compromise the validity of the study. First, the type of sampling (non-probabilistic), the type of design (posttest only with control), and the low sample size (n = 72) must be understood as important limitations. Results of this study are not representative of a large population, and a quasi-experimental design was used (Bulus & Dong, 2021; O'Neill et al., 2020; Rios, 2021). Moreover, the quantitative and qualitative data were obtained by means of non-standardized instruments. The validity and reliability of these instruments have been neither analyzed nor tested. These facts must also be

understood as major limitations (Bastian, 2017; Margulieux et al., 2019). Finally, other factors that may not be directly related to the COVID-19 pandemic may also have interfered in the results reported in this study (Dimosthenous et al., 2020; Semeraro et al., 2020). For example, the use of peer tutoring during the previous (2019–2020) school year by the teacher could have influenced the mathematics achievement outcome, resulting in an unconventional increase by students in the control group (Alegre et al., 2020). Moreover, there is a confounding variable which might have affected students' mathematics achievement, which is the teaching method: in-class education vs online education. As it was not possible to control this variable, it must be taken into account that students' achievement could have been influenced by the teaching method (Ribés et al., 2020). To address these limitations, further research is needed in the field with larger samples obtained through probabilistic sampling methods and using validated standardized instruments to address, in a more accurate and experimental way, the real effects of the COVID-19 pandemic on students' mathematics achievement.

Data Availability Statement

The datasets generated for this study can be found in the Open Science Framework data repository. https://osf.io/eupkb/?view_only=e9eaedba599c426184ec5d43a3cec6a8

Authorship Contribution Statement

Moliner: Concept, design, critical revision of manuscript, supervision, securing finding, technical support, final approval. Alegre: Data acquisition, data analysis, drafting manuscript. Lorenzo-Valentin: critical revision of manuscript, supervision

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