

Article

A COVID-19 Pandemic Sustainable Educational Innovation Management Proposal Framework

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Abstract: The COVID-19 pandemic has promoted a big change in the educational sector. Suddenly, teachers, professors, and students had to migrate from presential classes to the online system without prior notice or a training course. This paper aimed to verify how the need of a rapid change to the online system in response to the impossibility of keeping the presential system due to the mandatory social distancing imposed by the COVID-19 pandemic has affected relationships and performance of teachers, professors, and students, as well as review the technologies and procedures adopted by them to innovate and achieve sustainable education. To address the empirical side of this exploratory research, the authors of this paper sent an email questionnaire to kindergarten, elementary and high school teachers in the City of Rio de Janeiro (Brazil), as well as to professors of the top 197 Brazilian universities. To address theoretical side of this exploratory research, an investigation was carried out through scientific databases. The data were analyzed with SPSS (Statistical Package for the Social Sciences), version 22.0, and with Microsoft Excel 2007. As a result, this paper showed that social isolation and transition to the online system greatly affected the work conditions of teachers and professors, as well as the learning process of students. Anyway, sustainable actions were taken to overcome these challenges. Furthermore, this paper proposed a framework that might support the development of new studies, filling the literature gap on the subject.

Keywords: COVID-19; education; innovation; Industry 4.0; social isolation; teacher training course; information and communication technologies



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1. Introduction

The COVID-19 pandemic has triggered many challenges for all human beings, and one of the biggest challenges happened in education where schools and universities were forced to interrupt their presential (face-to-face) activities to migrate to the online system (e-learning). The study conducted by Aguilera-Hermida [1] showed that students prefer face-to-face classes and that the online system caused a drop in motivation, self-efficacy, and cognitive engagement. Furthermore, the study conducted by Asbury et al. [2] affirmed that because of the rapid change, parents and students reported such feelings as loss, worry, and change of mood and behavior.

On the other hand, the use of the Internet and technologies registered an extraordinary growth after COVID-19 emerged. Holt et al. [3] affirmed that students appreciated the flexibility, novelty, and the ability of expanding and interacting with the outside world.

This paper aimed to analyze how the need of a rapid change to e-learning in response to the impossibility of keeping the presential system due to the mandatory social distancing imposed by the COVID-19 pandemic has affected relationships and performance

of teachers, professors, and students, as well as review the technologies and procedures adopted by them to achieve sustainability in education. The analyses were based on an email questionnaire sent to kindergarten, elementary and high school teachers in the City of Rio de Janeiro (Brazil) [4], as well as to professors of the top 197 Brazilian universities [5].

This paper is structured in the following way. Firstly, it presents the introduction. Secondly, it describes theoretical background. Thirdly, it presents materials and methods. Fourthly, it provides the results and discussion. Finally, it is concluded and presents limitations and directions for future studies.

2. Theoretical Background

This section aims to present theoretical research background. In theoretical background, this paper included a survey developed using scientific databases. The search, without the year limitation, considered the following research expression: (“procedure”) AND (“social isolation”) AND (education)) AND (“technology”) AND (“social isolation”) AND (education)); after the quality check and duplication removal, the authors of this paper obtained 47 papers that were read, analyzed, and summarized, similarly to Ceryno et al. [6], Thomé et al. [7], and Hollmann et al. [8].

Educational System and Distance Learning

The COVID-19 pandemic has created a catastrophe in the health sector and was disruptive to several other sectors [9], it has changed the everyday life [10,11], and has forced the delivery off high-quality health products [12]. Furthermore, COVID-19 has brought uncertainty and panic among people [13]. For the educational system, the COVID-19 pandemic has created challenges in the need of a rapid change to the online system in response to the impossibility of keeping the presential educational system due to mandatory social distancing [10,14–17].

Educational institutions have implemented distance learning solutions and digital platforms which shifted the educational paradigm. According to Papouli et al. [18], during the COVID-19 pandemic, digital technologies and platforms became part of the students’ life. The study conducted by the authors affirmed that these strategies were used to keep students engaged during the COVID-19 lockdown period.

E-learning is considered the main alternative to fulfilling educational objectives in the adverse conditions brought by the COVID-19 pandemic [19]. Before the COVID-19 pandemic, technological tools present at schools were limited to research tools. The COVID-19 pandemic has forced the education into further technologization [10,20] and the strategy allowed minimizing the catastrophe [9].

According to Benhima and Benabderrazik [21], e-learning will never replace the presential education, mainly due to the problems with connection and the lack of materials like laptops, mobile phones, and tablets. However, Dilmaç [22] affirmed that the use of technology in education has become a reality after COVID-19 emerged. It has eliminated time and space limitations, overcoming the constraints imposed by social isolation.

Rajhans et al. [23], Dente and Hashimoto [24], and Kim and Asbury [25] stated that teachers, professors, and students faced uncertainty and challenges due to the closure of schools and the consequent migration to distance learning. Among the students’ challenges, Kim and Padilla [26] listed the lack of a quiet and private workplace, unstable home Internet connection, lack of efficient parental support, and decline in student performance.

According to Rajhans et al. [27], the COVID-19 pandemic’s adverse conditions have brought an opportunity to restructure and innovate the educational system, while Schildkamp et al. [28] admitted that the COVID-19 pandemic has required an innovative use of technologies, which also demanded new skills and competencies from teachers, professors, and students. According to Naidoo, technology as an educational tool is increasingly used in education [29]. According to Dau et al. [30] and Scavarda et al. [31], the Industry 4.0 concepts are the key points for these improvements and changes. Without technological tools, education would have surrendered in the face of the COVID-19 pandemic [32]. Five themes

emerged from the study conducted by Code et al. [33] considering educational technology: student competency, equity and access, motivation, effectiveness, and sustainability.

Fischer et al. [34] and Morley and Clarke [35] invited the population to rethink learning in the digital age. According to them, new technologies were necessary, especially during the COVID-19 pandemic, but they were not enough. Going to school was not only to get information, but also to take part in the community and enjoy values. According to Colao et al. [36], in addition to other objectives, schools have a mission of socialization for students. According to Goh and Sandals [37], a profound discussion on the future provision of teaching and learning will be required. According to Owolabi [38], virtual schooling is a kind of schooling, and technology supports virtual schooling adequately. Nevertheless, Ibrahim et al. [39] affirmed that there was resistance from teachers, professors, and students against accepting technology in the educational sector as the only way of teaching. According to Archer-Kuhn et al. [15], Kharbach and Khallouk [40], and Daniel [41], it increased the engagement between technology, education, teachers, professors, and students. According to Loda et al. [16] and Morley and Clarke [35], teachers and professors were to expand their digital competencies boosted by the COVID-19 pandemic, and according to Nepal and Rogerson [42], the COVID-19 pandemic brought an opportunity for educational enhancement. The COVID-19 pandemic has pushed forward an educational revolution [43]. According to Torda [43], many changes that have come with the COVID-19 pandemic will make better educators, collaborators, and innovators, while Tracey and Tolan [44] affirmed that it is an opportunity to explore more effective teaching practices. The evidence has showed that the use of technologies must be viable in the post-COVID-19 world [45] and there is a need to evaluate and expand research to guide new teaching and learning practices [46].

A study conducted by Dinh and Nguyen [47] in Vietnam showed that undergraduate level students reported difficulties in online learning but, according to them, they were able to overcome these difficulties. The academic society had to adapt to the new scenario to achieve progress [48]. In addition, the study outlined by Khalil et al. [49] informed that the online system and synchronized online learning were very well-accepted by professors and students in Saudi Arabia. Khalil et al. [49] believe that the new modality represents a promising potential future for the education.

3. Materials and Methods

In Materials and Methods section, this paper presents the path traced to achieve its objectives. This research included a questionnaire sent to kindergarten, elementary and high school teachers in the City of Rio de Janeiro [4], as well as to professors of the top 197 Brazilian universities [5].

Methods

As its sample, this study had kindergarten, elementary and high school teachers residing in the City of Rio de Janeiro (based on the 2018 School Census (escolas.inf.br, 2018) [4] that registered 66,999 teachers in the city distributed between 2010 private schools, 1439 municipal schools, 457 state schools, and 28 federal schools), as well as professors of the top 197 Brazilian universities (according to the Folha de São Paulo University Ranking index—the RUF index) [5]. The RUF index evaluates universities through five indicators: innovation, quality of teaching, scientific research, assessment of the labor market, and internationalization. The pretest for questionnaire validation was conducted on a group of teachers and professors in September 2020. Only after fine adjustments, the questionnaire was cleared for the study sample.

To obtain a valid result and due to the impossibility of interviewing the entire population, the authors of this paper developed a random sample of the universe. In this way, in October 2020, an email was sent to all schools requesting teachers to answer a questionnaire (Appendix A). The email addresses were obtained through the Internet. The teachers and

professors authorized publication of the results under the condition that their names and institutions would be kept strictly confidential.

Considering kindergartens, elementary and high schools, 116 teachers answered the request, 81 of them (69.2%) being women, 35 (30.2%)—men. The participants of this research had the following profile: age—from 48 to 63 years (56.0%); years of experience—well-distributed in the range from 13 to 37 years (94.9%); classroom teachers (74.1%); municipal school (42.0%) or state school teachers (35.7%); high school (38.8%) or elementary school I teachers (29.3%); and Portuguese, English, or Spanish teachers (43.1%).

Considering the questionnaires sent to professors, 145 of them answered the request, 64 being women (44.1%), 81—men (55.9%). The participants of this research had the following typical profile: age—from 43 to 61 years (55.3%); years of experience—well-distributed in the range from 1 to 36 years (86.8%); classroom professors (82.1%); undergraduate professors (82.8%); federal university professors (49.7%); typically, professors in the area of Humanities (57.9%).

From the collected data, the authors of this paper built a database in an electronic spreadsheet and it was analyzed with SPSS (Statistical Package for the Social Sciences), version 22.0, and with Microsoft Excel 2007. For the characterization of the respondents, the teachers and professors, a descriptive analysis of the results of the variables was carried out through frequency distributions with the proportions of interest, as well as calculation of appropriate statistics for quantitative variables (minimum, maximum, average, median, standard deviation, percentiles, coefficient of variation—CV). The variability in the distribution of a quantitative variable was considered low with $CV < 0.20$; moderate—with $0.20 \leq CV < 0.40$, and high—with $CV \geq 0.40$.

Considering the boxplot, let Q_1 be the first quartile (or, equivalently, the 25th percentile) of the variable distribution; Q_3 —the third quartile (or, equivalently, the 75th percentile) of the variable distribution; and $IQR = Q_3 - Q_1$, the interquartile range. The theory of statistical analysis using the boxplot determines that the values of the variable found in the sample that are below $Q_1 - 1.5 IQR$ or above $Q_3 + 1.5 IQR$ are outliers or atypical values (based on Triola [50], Favero et al. [51], and Medronho et al. [52]). Figure 1 summarizes Theoretical Background and Materials and Methods sections.

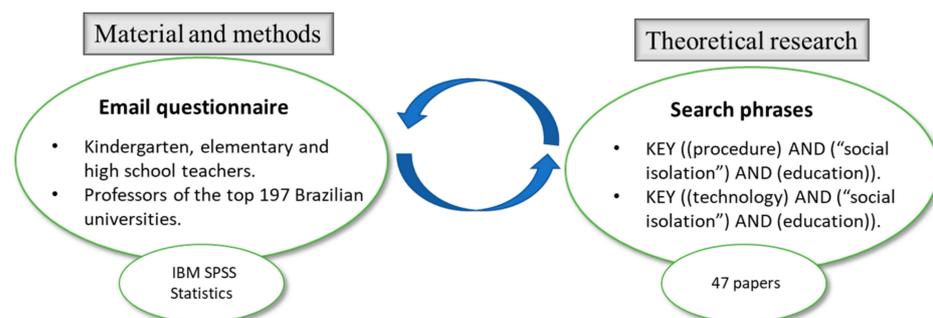


Figure 1. Summarization of Theoretical Background and Materials and Methods sections.

4. Results and Discussion

This study discusses the COVID-19 pandemic impacts upon the learning system from the perspectives of teachers and professors as well as of students and its implied influence towards a future sustainable teaching and learning scheme. The sustainable practices applied in many sectors [53,54] under the Sustainable Development Goals [55] and connecting with Industry 4.0 are ways to learning system analysis [56]. The data analysis of this paper considered questions 5, 6, 7, 8, 9, 19, and 38 of the email questionnaires submitted and answered by kindergarten, elementary and high school teachers of the City of Rio de Janeiro [4], as well as by professors of the top 197 Brazilian universities [5], i.e., the questions related to the social isolation interference with the relationships and performance of teachers, professors, and students, as well as to the technologies and procedures adopted by them to achieve sustainability during the COVID-19 pandemic. The questions were

divided as follows: two questions were of multiple choice, with the possibility to select more than one alternative, one question showed percentages ranging from 0% to 100%, and four were discursive questions. If the topic was unnecessary in the discursive question, the respondent would answer “No.”

For kindergarten, elementary and high school teachers, social isolation interfered with their work, as well as with the students’ learning process during the COVID-19 pandemic. For 96.4% of them, the main interferences were the lack of contact and interaction with students (40.5%), negative influence on student learning process (9.5%), accumulation of domestic chores (8.6%), increased workload (7.8%), lack of resources for some students to access online classes (6.9%), and increased anxiety and depression (6.0%). For 3.6% of the teachers, social isolation has not interfered with their work.

For 20.7% of the professors, social isolation has not interfered with their work during the COVID-19 pandemic. For the remaining 79.3%, the main social isolation interferences were the lack of contact, interaction, and dialogue with students (31.7%), workload increase (13.8%), inadequate home environment that has hindered synchronous classes (12.4%), accumulation of household chores and childcare (10.3%), increased stress and tiredness (10.3%), practical classes or field work (6.9%), and lack of space/time separation between professional and personal life (6.9%). Table 1 summarizes the distribution of the main interferences of social isolation with the work of teachers and professors during the COVID-19 pandemic.

Table 1. Frequency distribution of the main interferences of social isolation with the work of teachers and professors.

Interferences of Social Isolation with the Work of the Teachers	Number	%
Has not interfered	4	3.6
Lack of contact and interaction with students	47	40.5
Negative influence on the student learning process	11	9.5
Accumulation of domestic chores	10	8.6
Increased workload	9	7.8
Lack of resources for some students to access online classes	8	6.9
Increased anxiety and depression	7	6.0
Interferences of Social Isolation with the Work of the Professors	Number	%
Has not interfered	30	20.7
Lack of contact, interaction, and dialogue with students	46	31.7
Workload increase	20	13.8
Inadequate home environment that has hindered synchronous classes	18	12.4
Accumulation of household chores and childcare	15	10.3
Increased stress and tiredness	15	10.3
Practical classes or field work	10	6.9
Lack of space/time separation between professional and personal life	10	6.9

This research showed that social isolation interfered with the work of teachers and professors, but this inference did not prevent the development of activities. Everyone tried to overcome the difficulties by carrying out sustainable actions. It is important to acknowledge that the social isolation impact was more frequent among teachers than among professors. Teachers have closer relationships with their students than professors, so they experienced the social isolation interference stronger. Furthermore, professors carry out other activities, e.g., research, while most teachers work only in the classroom. For both types of professionals, the main interference was the lack of contact and interaction with students (declared by 40.5% of the teachers and 31.7% of the professors).

Considering the student learning process, for 97.4% of the teachers, the main interferences for students were the difficulty accessing the technologies used (13.8%), stress, psychological state of depression, or emotional distress of the students (13.8%), lack of face-to-face contact with the teacher (11.2%), restriction of exchanges between students (9.5%), little participation of students in classes (6.0%), lack of a routine, habit, or maturity

for studying alone (5.2%), and effect of distance on the dialog and impossibility of discussion (5.2%). For 2.6% of the teachers, social isolation has not interfered with the student learning process.

For 22.8% of the professors, social isolation has not interfered with the student learning process; for the other 77.2%, social isolation has presented factors that have interfered with the student learning process during the COVID-19 pandemic. The main interferences of social isolation with the student learning process were the lack of interpersonal relationships (15.2%), difficulty concentrating in the virtual classroom (9.0%), lack of interest (7.6%), lack of physical contact with the professor (6.9%), impossibility of dialog and discussions (6.9%), absence of practical and field classes (6.9%), and anxiety, depression, and other social illnesses. Table 2 summarizes the distribution on the main interferences of social isolation with the student learning process according to the perception by teachers and professors.

Table 2. Frequency distribution of the main interferences of social isolation with the student learning process according to the perception by teachers and professors.

Isolation Factors that Interfere with the Student Learning Process, Teachers' Perception	Number	%
Has not interfered	3	2.6
Difficulty accessing the technologies used for students	16	13.8
Stress, psychological state of depression, or emotional distress of the students	16	13.8
Lack of face-to-face contact with the teacher	12	11.2
Restriction of exchanges between students	11	9.5
Little participation of students in classes	7	6.0
Lack of a routine, habit, or maturity for studying alone	6	5.2
Effect of distance on the dialog and impossibility of discussion	6	5.2
Isolation Factors that Interfere with the Student Learning Process, Professors' Perception	Number	%
Has not interfered	33	22.8
Lack of interpersonal relationships, exchange interferences	22	15.2
Difficulty concentrating in the virtual classroom	13	9.0
Lack of interest	11	7.6
Lack of physical contact with the teacher	10	6.9
Impossibility of dialog and discussions	10	6.9
Absence of practical and field classes	10	6.9
Anxiety, depression, and other social illnesses	6	4.1

The teachers and the professors perceived the difficulties of their students in the period of social isolation. These difficulties could be attributed to the rapid change from the presential classroom to the online classroom and the lack of preparation of teachers, professors, and students for the new modality. Teachers highlighted the difficulty accessing the technologies, in this case, the Internet and computer access. Meanwhile, for 22.8% of the professors, there has been no interference, while for elementary and high school teachers, only for 2.6% of them there has been no interference. This result reinforces the idea of the greater interaction between teachers and students than between professors and students. For the analysis in Tables 1 and 2, the authors of this paper only considered the responses with high incidences. The low-incidence responses were disregarded.

Considering the technologies and procedures used by the teachers in their teaching practices during the COVID-19 pandemic, Table 3 presents the main ones that were adopted, and Table 4 presents the frequency distribution of the technologies and procedures that the teachers are becoming familiar with due to the COVID-19 pandemic.

Table 3. The technologies and procedures used by the teachers during the COVID-19 pandemical period.

Technologies and Procedures Used by the Teachers	Number	%
WhatsApp	88	75.9
Email	64	55.2
Google Classroom	64	55.2
YouTube	62	53.4
Google Meet	51	44.0
Zoom	43	37.1
Facebook	32	27.6
Microsoft Teams	31	26.7
Instagram	17	14.7

Table 4. Frequency distribution of the technologies and procedures that the teachers are becoming familiar with due to the COVID-19 pandemic.

Technologies and Procedures that the Teachers are Becoming Familiar with	Number	%
Google Meet	66	56.9
Zoom	60	51.7
Google Classroom	57	49.1
Microsoft Teams	49	42.2
WhatsApp	27	23.3
YouTube	26	22.4
Instagram	20	17.2
Email	13	11.2
None	11	9.5
Moodle	10	8.6
Facebook	9	7.8

The percentages for Tables 3 and 4 were calculated in relation to sample size N (116 teachers and 145 professors). The sum of the frequencies exceeded the value of N because the questions allowed multiple responses. Prominence went to WhatsApp, Email, Google Classroom, and YouTube in Table 3 and to Google Meet and Zoom in Table 4 as these resources were mentioned by more than 50% of the teachers. It is possible to notice that the expansion of the email, WhatsApp, and YouTube use was facilitated because these tools had already been popular before the COVID-19 pandemic. In the case of Google Meet and Zoom, these are friendly tools that facilitate the attempt of interaction between individuals.

Figures 2 and 3 show the training undergone by teachers and students to use technology during the COVID-19 pandemic. Figure 2 shows that the teachers had not undergone any training courses before starting to use the technologies (61.2%). Furthermore, according to this research, students entered the new educational system worse prepared than teachers. As Figure 3 shows, the percentage of the students who had not undergone any training courses before starting to use the teaching technologies used during the COVID-19 pandemic (94.0%) was even higher than among teachers.

The teachers' answers to the question about the training courses that they had attended and their distribution are in Table 5. The data in Table 5 show that the main training course routes for teachers were video classes, lives, lectures, and online courses on technologies (used by 18.1% of the teachers). The training courses offered by the Department of Education (56.0%), the training courses offered by the city hall (5.1%), and the training courses for Microsoft Teams (5.1%) were also taken by more than 5% of the teachers. Of the 31 teachers using Microsoft Teams, only six (19.4%) attended any training courses for this technology, corroborating the conclusion that most teachers had not undergone any training courses before starting to use technology. For students, 4.3% of the teachers declared that they

underwent training courses through pedagogical coordination, 1.7%—through YouTube tutorials, videos, and lectures.

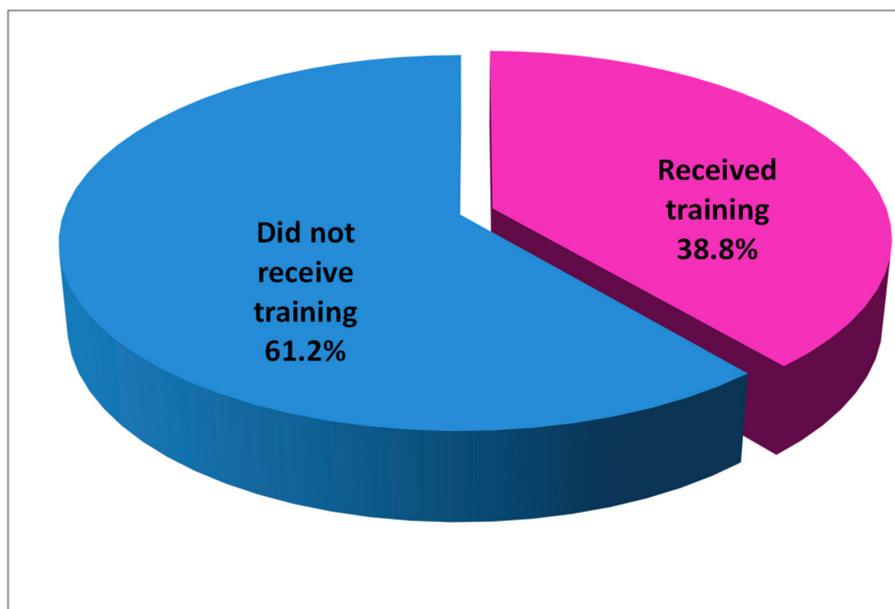


Figure 2. The percentage of the teachers who did some training courses to work with the new technologies during the COVID-19 pandemic.

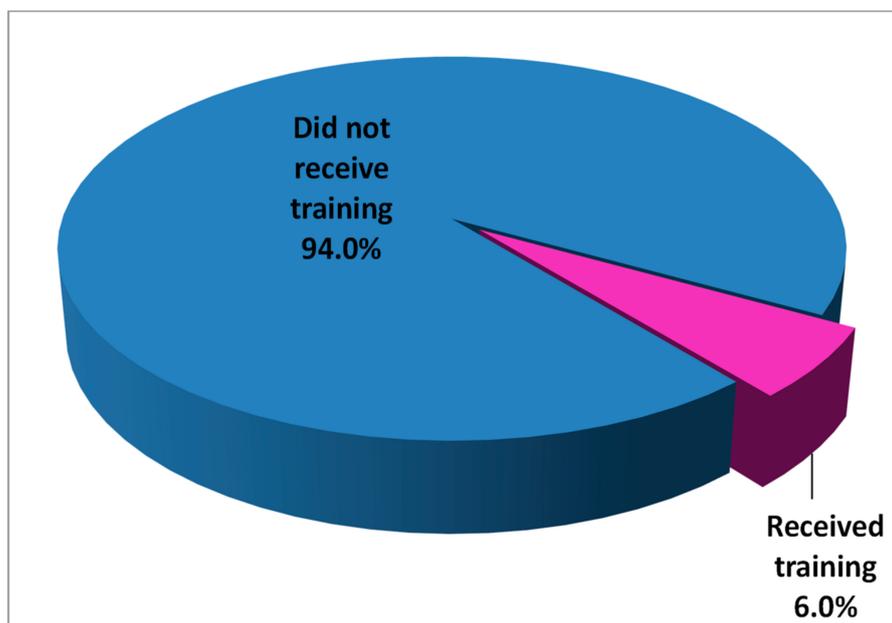
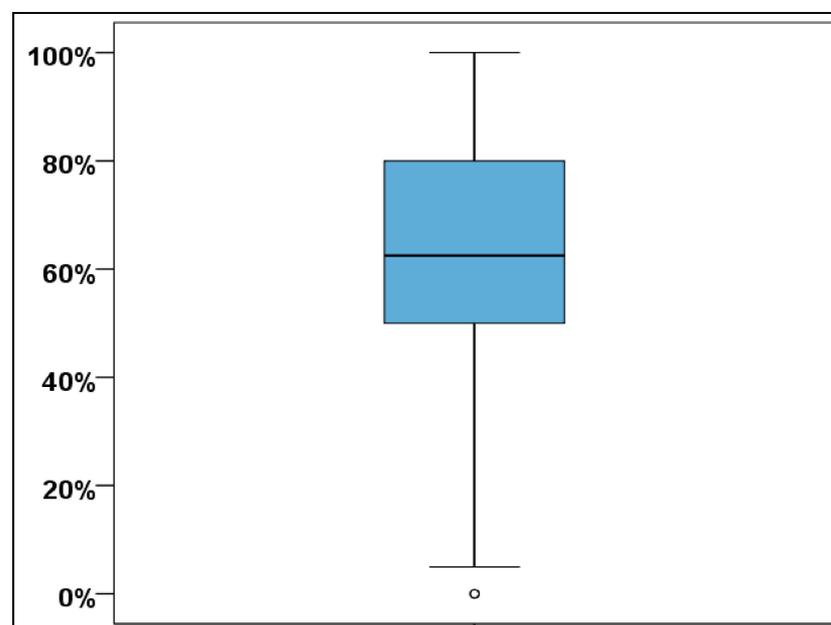


Figure 3. The percentage of the students who did some training courses to work with the new technologies during the COVID-19 pandemic according to the teachers' statements.

Table 5. Frequency distribution of the training courses attended to deal with the teaching technologies and procedures used during the COVID-19 pandemic.

Teachers' Training Pathway	Number	%
Did not attend any training course	71	61.2
Video classes, lives, lectures, and online courses	21	18.1
Training courses offered by the Rio de Janeiro Secretary of State for Education	7	6.0
Training courses offered by the city hall	6	5.1
Training courses for Microsoft Teams	6	5.1
Training courses provided by the institution	4	3.4
Students' Training Pathway	Number	%
Did not attend any training course	109	94.0
Training courses through pedagogical coordination	5	4.3
YouTube tutorials, videos, and lectures	2	1.7

When asked how proficient, on a scale from 0% to 100%, the teachers considered themselves to be regarding the use of the new technologies and procedures for teaching, the answers varied from 0% to 100%, with 0% being an atypical statement (represented by $^{\circ}$ in the boxplot in Figure 4). The mean score was 61.9%, quartile 1 was equal to 50.0%, the median was equal to 60.0%, quartile 3 was equal to 80.0%, and the standard deviation was equal to 26.2%, which resulted in a coefficient of variation equal to 0.42 (high variability), showing that the level of self-declared aptitude varied widely between the teachers. In this distribution, $Q_1 = 50.0\%$; $Q_3 = 80.0\%$; and $IQR = Q_3 - Q_1 = 30.0\%$. Therefore, the values below $Q_1 - 1.5 IQR = 50.0\% - 1.5 \times 30.0\% = 50.0\% - 45.0\% = 5.0\%$ are atypical, so 0%, which is less than 5%, is an outlier for this data distribution.

**Figure 4.** Boxplot of the percentage of how proficient the teachers considered themselves to be regarding the use of the new technologies and procedures for teaching.

Considering the professors of the top 197 Brazilian universities [5], Table 6 shows the frequency distribution of the technologies and procedures used in the teaching practice during the COVID-19 pandemic. The technologies used by more than 50% of the professors were email, Google Meet, and WhatsApp. Table 7 shows the frequency distribution of the technologies and procedures that the professors are becoming familiar with due to the COVID-19 pandemic. The technology that they are becoming familiar with due

to the pandemic declared by more than 50% of the professors was Google Meet. The percentages for Tables 6 and 7 were calculated in relation to sample size N (116 teachers and 145 professors). The sum of the frequencies exceeded the value of N because the questions allowed multiple responses.

Table 6. Frequency distribution of the technologies and procedures used in the teaching practice during the COVID-19 pandemic.

Technologies and Procedures Used in the Teaching Practice during the COVID-19 Pandemic	Number	%
Email	104	71.7
Google Meet	100	69.0
WhatsApp	83	57.2
Moodle	56	38.6
Google Classroom	52	35.9
Zoom	52	35.9
YouTube	47	32.4
Microsoft Teams	33	22.8
Skype	19	13.1
Facebook	11	7.6
Blackboard	8	5.5
Instagram	7	4.8
Brazilian National Education and Research Network (RNP)	3	2.1
Google Drive	2	1.4
Graphics tablets	2	1.4
OBS Studio	2	1.4

Table 7. Frequency distribution of the technologies and procedures that the professors are becoming familiar with due to the COVID-19 pandemic.

Technologies and Procedures that the Professors are Becoming Familiar with Due to the COVID-19 Pandemic	Number	%
Google Meet	90	62.1
Zoom	55	37.9
Google Classroom	45	31.0
Microsoft Teams	41	28.3
Moodle	36	24.8
YouTube	32	22.1
WhatsApp	20	13.8
Email	17	11.7
Instagram	8	5.5
Blackboard	7	4.8
None	7	4.8
Skype	5	3.4
OBS Studio	3	2.1
iMovie	2	1.4
Graphics tablets	2	1.4
Stream Yard	2	1.4

Regarding the technologies used and the technologies they are becoming familiar with, the teachers and professors presented similar results. In the case of the professors, email and WhatsApp had already been popular before the COVID-19 pandemic, while Google Meet had been used already for research meetings. As shown in Figure 5, most of the professors had not undergone any training courses before starting to use the technologies (53.1%). Considering the students, 82.1% did not undergo any training courses and only 13.8% of the students had a training course as seen in Figure 6.

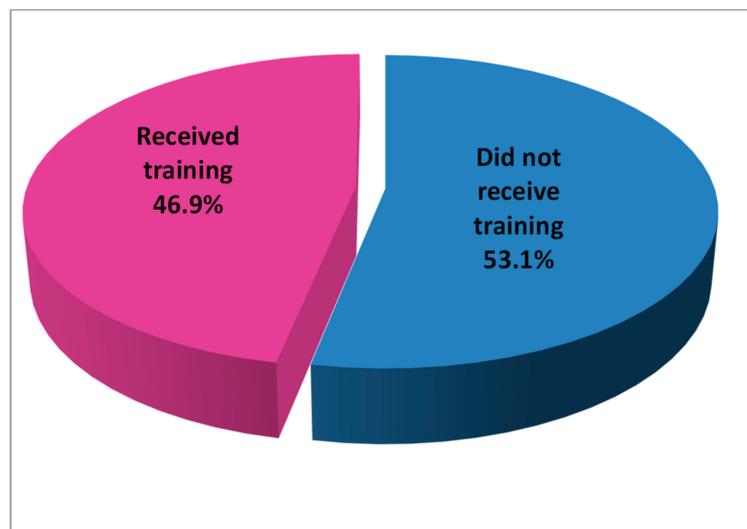


Figure 5. The percentage of the professors who attended some training courses to work with the new technologies during the pandemic.

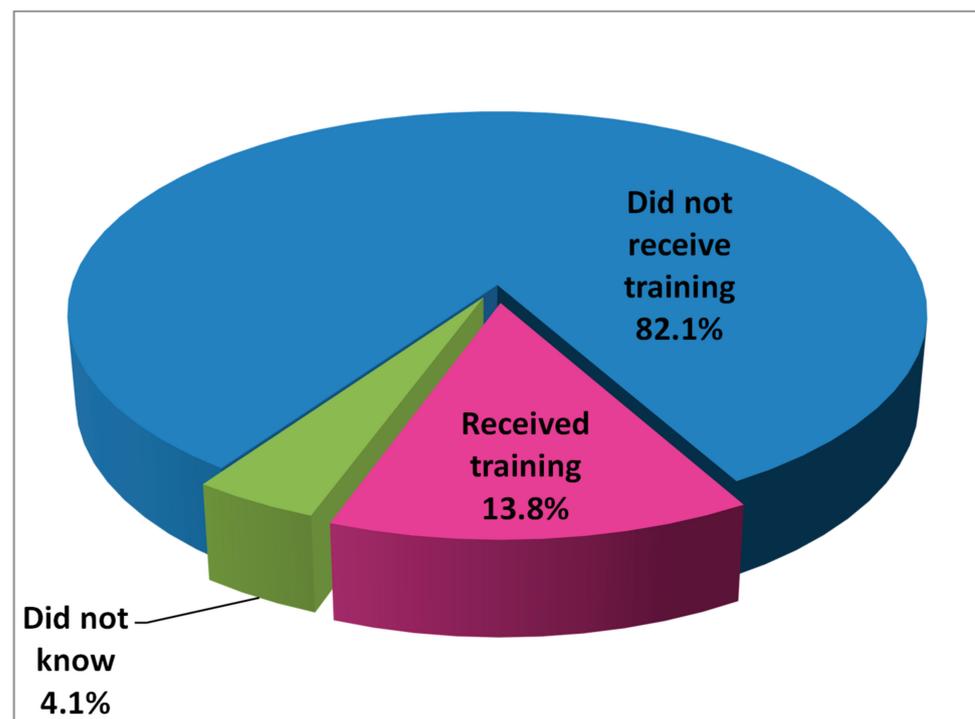


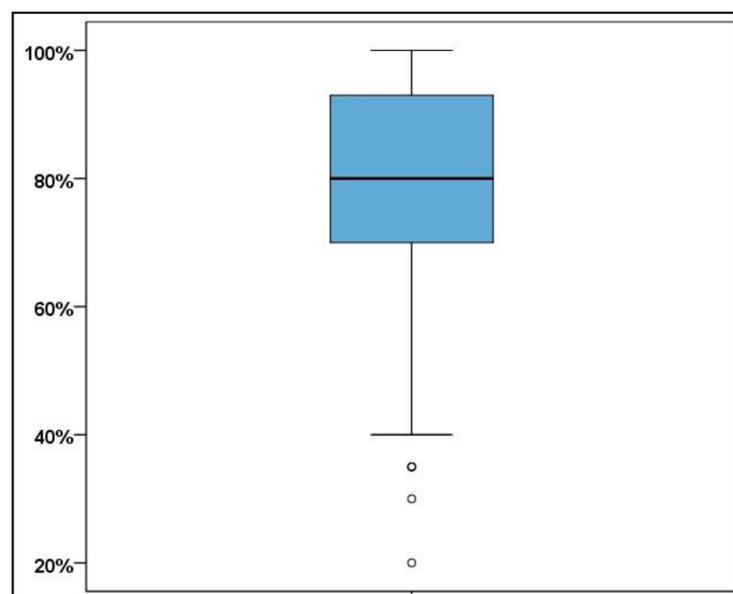
Figure 6. The percentage of the students who attended some training courses to work with the new technologies during the COVID-19 pandemic according to the professors' statements.

The answers to the question regarding the type of training courses taken by the professors and students are presented in Table 8. Table 8 shows that the main training course routes for the professors were training courses, videos, podcasts, and online tutorials (25.5%), and training courses on the use of tools offered by their institutions (21.4%) were also taken. For students, 7.6% of the professors declared that they had workshops offered by the institutions and 6.2% attended training courses, videos, podcasts, and online tutorials.

Table 8. Frequency distribution of the training courses attended to deal with the teaching technologies and procedures used during the COVID-19 pandemic.

Professors' Training Pathway	Number	%
Did not attend any training courses	77	53.1
Training courses, videos, podcasts, and online tutorials	37	25.5
Training on the use of tools offered by their institutions	31	21.4
Students' Training Pathway	Number	%
Did not attend any training courses	119	82.1
Training on the use of tools offered by their institutions	11	7.6
Did not know	6	4.1
Training courses, videos, podcasts, and online tutorials	9	6.2

When asked how proficient, on a scale from 0% to 100%, they considered themselves to be regarding the use of the new technologies and procedures for teaching, the professors' responses ranged from 20% to 100%, with statements below 40% being atypical (represented by ° in the boxplot in Figure 7). The mean score was 79.6%, quartile 1 was equal to 70.0%, the median was equal to 80.0%, quartile 3 was equal to 94.0%, and the standard deviation was equal to 18.2%, which resulted in a coefficient of variation equal to 0.22, showing that the level of self-reported aptitude varies moderately among higher education professors. In this distribution, $Q_1 = 70.0\%$; $Q_3 = 94.0\%$; and $IQR = Q_3 - Q_1 = 94.0\% - 70.0\% = 24.0\%$. Therefore, the values below $Q_1 - 1.5 IQR = 70.0\% - 1.5 \times 24.0\% = 70.0\% - 36.0\% = 34.0\%$ are atypical, so the values below 34% that appeared in the sample were marked with ° as they are atypical values for this data distribution.

**Figure 7.** Boxplot of the percentage of how proficient the teachers considered themselves to be regarding the use of the new technologies and procedures for teaching.

As presented in this research, neither the teachers or professors nor the students were formally trained or prepared to deal with the new technologies required during the COVID-19 pandemic. They tried on their own to adapt themselves to the new demands of the period and to surpass the deficiencies related to the Internet and computer access that makes unfeasible the technology access. Furthermore, social isolation as a measure to avoid contamination by COVID-19 interfered with their performance, mainly due to the lack of contact or relationships between them. To minimize the impacts of COVID-19 and take advantage of the new experience obtained and the innovations outlined during the COVID-19 pandemic, a framework can be adopted as follows. It is important to highlight

that this framework is a starting point which can be an important tool to help researchers to develop new studies on this subject.

- To minimize the feeling of loneliness caused by social isolation, online meetings should be promoted to integrate professors, teachers, and students.
- Institutions should provide guidance or training courses to the professors, teachers, and students on the use of these technologies and procedures adopted during the COVID-19 pandemic.
- Institutions should maintain the use of the technologies and procedures that were adopted well during the COVID-19 pandemic, such as email, Google Meet, and WhatsApp, in the post-COVID-19 period.
- Institutions should provide an area of school or university to be eventually used by the professors, teachers, and students to respect the social isolation requirements. The idea of these areas is to overcome difficulties with Internet access and lack of equipment like laptops.

5. Conclusions

The COVID-19 pandemic has promoted a significant change in our daily lives, and one of the main changes occurred in education. Social isolation as a measure to avoid contamination by COVID-19 greatly affected the work of teachers and professors and the student learning process, and they were invited to innovate. This innovation allowed the development of sustainable actions that prevented a collapse. In the educational sector, the innovation was mainly due to the transition from presential classes to online classes. Many difficulties were encountered to carry out online classes, mainly because online classes were mixed with daily home routines without previous preparation for the transition. The highlight can be given to the lack of training courses and the difficulties with Internet access.

Ayeleke et al. [57] affirmed that a training course using flexible and multiple techniques tailored to the context can improve individual competencies and performance. Furthermore, Internet access is still a big challenge to be overcome in Brazil. The Brazilian Network Information Center [58] affirmed that the COVID-19 pandemic highlighted how much technologies are part of the Brazilian households' routine. Since the COVID-19 pandemic took place, it could be noticed that a significant part of the Brazilian population is digitally excluded. In 2019, 20 million Brazilian households did not have Internet access. Besides, although the number of Internet users increased since 2019, this use was mostly restricted to mobile phones, which reduced the advantages of online opportunities, mainly in cultural activities, school search, and online courses. Furthermore, a computer is not an available tool for most people of the D and E social classes due to low level of education and lack of familiarity with Internet tools [58].

The innovation in the technologies and teaching procedures has been a great challenge faced by teachers, professors, and students, together with keeping the students' attention during online classes. Part of these difficulties mentioned by the teachers and professors was related to the restricted means of teaching in Brazil, where there is limited technological device access. These difficulties are more frequent among students from public schools and public universities. As the COVID-19 pandemic took place rapidly, there was no time to prepare, test, and reorganize to start with the new ways of teaching.

In any case, teachers, professors, and students sought to surpass these difficulties, often without the support of their institutions, with their own resources. This reinforces the category's commitment to the teaching philosophy. Most of the teachers, professors, and students already feel able to work with the new technologies and procedures presented during the COVID-19 pandemic.

However, these are not only the difficulties that have marked the COVID-19 pandemic. Many of the innovations initiated during this period are expected to continue in the post-COVID-19 period, such as the inclusion of technologies and online meetings in the educational plan. Everybody in the educational and other sectors are invited to rethink

their activities to understand what can continue online and what should return to presential classes, taking advantage of the best of each strategy.

The use of technology presents as fundamental in several situations, as can be seen in the educational sector during the COVID-19 pandemic. Some technologies are interesting because they do not require extensive knowledge of complex and complicated systems [59]. According to Wu [60], more in-depth research on the role and use of technology in different areas of human knowledge is becoming increasingly relevant. This idea has been reinforced by Weber [61] who affirmed that technology is proving to be a strong driver of sustainable development. Carvalho et al. [62] state that technologies, human and organizational aspects of the process can improve effectiveness and prove to be essential.

According to Santos et al. [63], it is beneficial to emphasize that the use of technologies can facilitate the teaching–learning process. To not use technology would be a step backwards for the education. Teachers, professors, and students are in the process of adaptation where the main point is to provide new ways of teaching and learning. Let us be optimistic. It is a great opportunity of sharing knowledge and to perceive how technological tools can enable access to learning and complement presential education in the post-COVID-19 period [63,64].

Limitations and Directions for Further Research

This study has limitations regarding the return of the questionnaires and the impossibility of interviewing the entire population. Moreover, the results illustrating the students' training was indicated according to the teachers and professors' statements and may be very subjective. Furthermore, as this is an exploratory study, the authors of this paper did not aim to confirm the hypotheses that had been postulated.

For future studies, the idea is to observe the students who experienced the COVID-19 pandemic to analyze the interference of the transition to the online system with their research and learning performance and their need of training courses during the COVID-19 pandemic according to their perception. Another idea for future agenda is to verify the benefits and harms of online studying and to understand which characteristics of online studying will be maintained in the post-COVID-19 period, expanding the discussion of the framework presented in this study. Furthermore, this exploratory study should be expanded to other Brazilian cities and to other emerging markets.

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Appendix A

Multidisciplinary Research: Influence of Pandemics on Teaching and Learning

Dear Teacher,

Ana Dias, a colleague of many of us, is conducting a multidisciplinary doctoral research in Production Engineering at CEFET/RJ on the influence of the COVID-19 pandemic on the teaching and learning processes in Brazilian public and private schools and humbly requests you to participate by answering the questionnaire. Please feel free to contact her by email in the event of any doubts (missdias@gmail.com).

FILL OUT FORM

Email address:

Name:

I authorize the results of this research to be presented and published under the condition that my name and my institution will be kept strictly confidential.

Yes

No

Sex:

Age:

Years of teaching experience:

I am answering about the perspective of my performance before the pandemic in:

Classroom teaching

E-learning (EL)

Type of school I teach at (choose one):

Municipal public school

State public school

Federal public school

Private school

Other:

Class level I teach (choose one):

Pre-school education

Elementary school I (years 1-5)

Elementary school II (years 6-9)

High school

Technical education

Graduate degree

Bachelor's degree

Residency

Specialization

MBA

Professional Master's degree

Academic Master's degree

Professional doctorate (PHD)

Doctoral (PHD) degree

Post-doctoral degree

Other:

The discipline that I teach and that I would like to use as a parameter for this research (write only one discipline. For example: Administration, Biology, Law, Economics, Physical Education, Nursing, Mechanical Engineering, Philosophy, Physics, History, Informatics, Mathematics, Music, Nutrition, Portuguese, Social Work, Theology, Tourism):

1. The difficulties and challenges I encounter in my teaching practice during the pandemic are (write "No" if this does not apply):
2. I can overcome and adapt to these difficulties and challenges as follows (write "No" if this does not apply):
3. The facilities and opportunities I find in my teaching practice during the pandemic are (write "No" if this does not apply):
4. I can take advantage of these facilities and opportunities as follows (write "No" if this does not apply):

5. The technology(ies) and procedure(s) I use for my teaching practice during the pandemic are (you can choose more than one):
 - Blackboard
 - Email
 - Facebook
 - Google Classroom
 - Google Meet
 - Instagram
 - Microsoft Teams
 - Moodle
 - Skype
 - YouTube
 - WhatsApp
 - Zoom
 - None
 - Other:
6. The technology(ies) and procedure(s) that I am becoming familiar with because of the pandemic are (you can choose more than one):
 - Blackboard
 - Email
 - Facebook
 - Instagram
 - Google Classroom
 - Google Meet
 - Microsoft Teams
 - Moodle
 - Skype
 - YouTube
 - WhatsApp
 - Zoom
 - None
 - Other:
7. The training(s) I have attended to work with this(these) technology(ies) and procedure(s) are (write "No" if this does not apply):
8. I consider myself apt to use this(these) technology(ies) and procedure(s) (0%—totally unfit, 100%—totally fit):
9. Work from home and the consequent social isolation interfere with my work as follows (write "No" if this does not apply):
10. I try to establish EQUALITY for and between my students during the pandemic as follows (write "No" if this does not apply):
11. The percentage that I am managing to establish for EQUALITY is (write "No" if this does not apply):
12. I try to establish QUALITY for and between my students during the pandemic as follows (write "No" if this does not apply):
13. The percentage that I am managing to establish for QUALITY is (write "No" if this does not apply):
14. I try to establish JUSTICE for and between my students during the pandemic as follows (write "No" if this does not apply):
15. The percentage that I am managing to establish for JUSTICE is (write "No" if this does not apply):
16. The sensations, feelings, and emotions that describe my teaching experience during the pandemic are (you can choose more than one):
 - Joy
 - Love

- Calm
 - Jealous
 - Compassion
 - Fault
 - Despair
 - Hope
 - Strangeness
 - Euphoria
 - Excitement
 - Happiness
 - Frustration
 - Gratitude
 - Hostility
 - Humor
 - Indifference
 - Fear
 - Nostalgia
 - Hate
 - Dread
 - Rage
 - Satisfaction
 - Surprise
 - Boredom
 - Nervous tension
 - Sadness
 - None
 - Other:
17. The difficulties and challenges of my students with the new teaching methods practiced during the pandemic are (write "No" if this does not apply):
 18. The facilities and opportunities of my students with the new teaching methods practiced during the pandemic are (write "NO" if this does not apply):
 19. Work from home and the consequent social isolation interferes with the performance and learning of my students as follows (write "No" if this does not apply):
 20. Defining student performance as the assessment of knowledge acquired in the classroom, the percentage of my students with a drop in school performance during the pandemic is:
 21. The percentage of my students with NO CHANGE in school performance during the pandemic is:
 22. The percentage of my students with INCREASED school performance during the pandemic is:
 23. I interact with my students with DECREASED school performance as follows (write "No" if this does not apply):
 24. I interact with my students with NO CHANGE in school performance as follows (write "No" if this does not apply):
 25. I interact with my students with INCREASED school performance as follows (write "No" if this does not apply):
 26. Defining student learning as the process of behavior change obtained through experience built by emotional, neurological, relational, and environmental factors, the percentage of my students with WORSENERED learning during the pandemic is:
 27. The percentage of my students with NO CHANGE in learning during the pandemic is:
 28. The percentage of my students with IMPROVED learning in the pandemic is:
 29. I interact with my students with WORSENERED learning as follows (write "No" if this does not apply):

30. I interact with my students with NO CHANGE in learning as follows (write “No” if this does not apply):
31. I interact with my students with IMPROVED learning as follows (write “No” if this does not apply):
32. The percentage of familiarity of my students with WORSENER learning with the technology(ies) and procedure(s) adopted during the pandemic is (0%—unfamiliar, 100%—familiar):
33. The percentage of familiarity of my students with NO CHANGE in learning with the technology(ies) and procedure(s) adopted during the pandemic is (0%—unfamiliar, 100%—familiar):
34. The percentage of familiarity of my students with IMPROVED learning with the technology(ies) and procedure(s) adopted during the pandemic is (0%—unfamiliar, 100%—familiar):
35. The percentage of familiarity of my students with WORSENER school performance with the technology(ies) and procedure(s) adopted during the pandemic is (0%—unfamiliar, 100%—familiar):
36. The percentage of familiarity of my students with NO CHANGE in school performance with the technology(ies) and procedure(s) adopted during the pandemic is (0%—unfamiliar, 100%—familiar):
37. The percentage of familiarity of my students with IMPROVED school performance with the technology(ies) and procedure(s) adopted during the pandemic is (0%—unfamiliar, 100% familiar):
38. The trainings that my students attended to use the technology(ies) and procedure(s) during the pandemic are (write “No” if this does not apply):
39. My students’ sensations, feelings, and emotions that describe their learning experience during the pandemic are (you can choose more than one):
 - Joy
 - Love
 - Calm
 - Jealous
 - Compassion
 - Fault
 - Despair
 - Hope
 - Strangeness
 - Euphoria
 - Excitement
 - Happiness
 - Frustration
 - Gratitude
 - Hostility
 - Humor
 - Indifference
 - Fear
 - Nostalgia
 - Hate
 - Dread
 - Rage
 - Satisfaction
 - Surprise
 - Boredom
 - Tension
 - Sadness

- () None
() Other:

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