Design Implications for Interactive and Analogue Technologies supporting Distance Education: A Longitudinal Mixed-Method Study during the Pandemic

Duarte L. Sousa[1], Pedro F. Campos[1,2] and Vanessa Cesário[2]

[1] Faculty of Exact Sciences and Engineering, Universidade da Madeira, Campus da Penteada, 9020-105 Funchal, Portugal. 2024604@student.uma.pt;
[2] ITI/LARSyS, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal
pedro.campos@iti.larsys.pt; vanessa.cesario@iti.larsys.pt

Abstract. This study investigates COVID-19's impact on the education system by gathering data on how interactive and analogue technologies mitigated such disruption. It also analyses how and if educational approaches were modified during the pandemic. The procedures consisted of the analysis of evidence retrieved from three surveys delivered to three stakeholder groups: teachers, students, and parents (N=215), crossed with an examination of a set of 5-week longitudinal interviews (30) with the same groups (N=6). The results of the analysis are used to derive a set of important design implications that: (1) highlight shortcomings of the distance education (DE) strategies used during COVID-19 and how they can be mitigated; (2) empower the stakeholders with innovative pedagogical approaches that information communication technologies can foster, thus optimising DE; (3) promotes positive learning experiences supported with scientific evidence. Conclusions are derived from a collaborative reflection on the stakeholders' daily needs during unpredictable circumstances.

Keywords: HCI in the pandemic. Design Implications. Multi-User Interaction /Cooperation. User Experience based approaches. Distance learning approaches. Teaching communities. Learning communities. User-centred design.

1 Introduction

COVID-19 pandemic's1 global impact is still a complex and challenging phenomenon to understand, especially in the beginning when contradicting information spread as

[1] WHO. n.d. "Coronavirus Disease (COVID-19) Pandemic." www.Euro.Who.Int. https://www.euro.who.int/en/health-topics/healthemergencies/coronavirus-covid-19/novel-coronavirus-2019-ncov, last accessed 2020/10/28.

fast as the virus itself. The lockdown and self-isolation, as non-pharmaceutical solutions, seemed to be the only solution to "flatten the curve"2. This fact resulted in the closure of schools in more than 190 countries by mid-April, thus impacting 1.6 billion students; that is, 94% of the world's student population is currently affected by the pandemic, according to the United Nations (UN) [1]. In some countries, the inability to meet face-to-face (F2F) with teachers and classmates was mitigated by information communication technologies (ICTs), now playing an essential role in maintaining prior bonds. Early on, schools would reach out to students via email; however, as the situation escalated, discussions on the rapid implementation of other teaching and learning solutions gained extra arguments. At the same time, the pandemic crisis disclosed several shortcomings in the educational system that, despite all innovative methodologies and technologies accessible, failed to implement flexible education protocols or strategies in time for such disruptive events. The UN also refers that most countries implemented ICT guidelines to support students' instruction continuity, during the pandemic, as opposed to almost 40% of least developed nations and "refugee and forcibly displaced children are further marginalised and deprived of access to support services offered through schools" [1].

Communication is an essential element of learning which is intrinsically assumed as F2F. The core aspect of Distance Education (DE) is the student(s) and teacher's physical and temporal separation. As a phenomenon, DE has more than 150 years and might be defined as "any approach to instruction in which the majority of the instruction occurs while educator and learner are not in each other's presence" [2]. Thus, the teacher and student's interaction should be aided through various mediums, usually linked to that time's dominant communication technology. So, any instruction can happen via any technology, therefore becoming a form of DE "when it is used as the sole or primary means of teaching" [3, 4].

DE encompasses Virtual Education or Virtual School (VS) and Online Education, as well as distance learning and distance teaching, and defines the position in which one is relating to the other; therefore, distance education is "the term that correctly describes a relationship that has two sides, teacher and learner" [3]. Even though DE is used as a generalised term for remote learning, the term VS acquired momentum when referring to K-12 education.

1.1 Scarce research on the education system's disruption

The unprecedented non-pharmaceutical measures, such as social distancing, taken to diminish the expansion of SARS-CoV-2 led to a historic disruption of the world's education system. Despite the lack of consensus, DE teaching and learning methodologies and tools were used to progress the student's instruction continuity. DE is seen with apprehension as a valid and effective education method even though former compari-

[2] Cordis. 2020. “Trending Science: Why Has ‘Flatten the Curve’ Become the Public Health Mantra in the Global Fight against Coronavirus?” Retrieved October 10, 2020 from Cordis.Europa.Eu/, 26 Mar. 2020, cordis.europa.eu/article/id/415751-flatten-curve

sons with face-to-face methods proved inconclusive or marginally better. These previous studies on DE did not comprehend the pandemic's added difficulties such as lack of resources, for example, detrimental to the student's learning progress or its impact on the technological mediums, seen merely as tools to "deliver instruction but not influence student achievement" [5–7].

The proficient literature on crisis management does not generally comprehend the education system, from the lower to the higher levels. Such rare information is seldom "addressed in 'medical' journals and more recently boosted by the 'knowledge management' scholars" [8] or according to its macroeconomic effects on the affected regions [9, 10]. Research on disruptive events in the education system, like Hurricane Katrina, in the United States of America, "can provide a rough sense of how additional time out of school" [7] will reflect on students' return to school and their learning progression. Yet a distinction must be made between a disease outbreak and floods, earthquakes, fires or snow hazards due to its dynamics and possible recurring nature [8].

1.2 K-12 Education Pandemic Consequences

The UN claims that instructional loss will occur and jeopardise the efforts of many decades, especially for the underprivileged children and adults, mostly young girls and women, who saw their learning opportunities diminished due to the pandemic. The Organisation for Economic Cooperation and Development (OECD) [11] refers to other authors who allude to the minor effects of school closures on student's achievements, found in the literature; namely, the prolonged school closure period in 2011 derived from the Christchurch earthquakes, mainly due to the teachers' focus on what students should learn. Although shorter in duration, such sudden closures disturbed the learning process; therefore, they might pose some analogous consequences in the school system and how the set process should continue. Even though insightful, Kuhfeld et al. [7] state that some of these studies could have several flaws, like not studying the impact on different demographics, school poverty, or the impact of the current technological solutions used for remote learning. Another critical issue is the pressing potential wave patterns and re-infection of SARS-CoV-2 in certain areas or populations, so the correlation now being made with education lost time with what happens during those events might not be entirely appropriate. Students' accomplishments are difficult to determine in such a climate and their impacts on their academic future.

1.3 Students’ learning struggles

As referred by OECD, some authors claim the doubts about the learning progression due to the already precarious situation will aggravate by a foreseeable economic crisis. Therefore, students from impoverished communities will have increased non-academic issues, such as food insecurity, further lack of resources and overall socioeconomic fragility to affect their learning progression. Consequently, this will lead to more inequalities, such as learning variability, and school abandonment, as indicated by OECD.

Moreover, the UN refers that such a crisis will lead to an instructional loss, thus threatening the progression of decades of learning opportunities for learners in poor communities, especially young girls and women.

For Van Lancker and Parolin [6] and Harmey and Moss [12], the summer learning loss in American students is a predictor of Covid-19's effects on students' learning variability, especially those from lower socioeconomic backgrounds. Although other authors refer to the minimal impact of school closures on students' learning continuity, Kuhfeld et al. [7] identify pressing flaws in these studies, like the lack of impact on different demographics, impoverished communities, or the new technological mediums used in DE. As indicated by OECD, some studies claim that the student's precarious learning progression will aggravate among those of lower socioeconomic backgrounds. Consequently, more inequalities will arise, leading to an increased learning variability and school abandonment [13].

1.4 Unsupportive household

Despite the education system's response, the students' learning variability will be emphasised by the families' socioeconomic delicate conditions [14]. Additionally, Kuhfeld et al. [7] also refer to the added conflict to attending school and the pressing need for supplementary technological mediums as supportive learning tools affecting 50% of low-income families. Moreover, "children from lower-income households are likely to struggle to complete homework and online courses because of their precarious housing situations." [6] Also, due to their parent's lower education impediment to assisting their children in their academic chores, thus relying on their siblings, extended family members or friends [14]. According to OECD, the progenitors conflicted as well to balance their work routines, family duties and the extended role in caring for the students' academic and emotional needs, acting as the learners' primary motivator during the pandemic event.

2 Methods

2.1 Mixed-method longitudinal study procedures

This study seeks to examine the education stakeholders (teachers, students, and parents) unique perspectives on the repercussions of educational adjustment in early 2020 due to the Covid-19 pandemic. The data collection was performed between March and April 2020 amid the compulsory schools' closures. It also provided valuable insight on the practices, the overall behavioural impacts of the set stakeholders and their teaching, learning and assistance procedures' transformation throughout the school closures and consequent educational methods' shift. Data also helped outline pressing issues identified by stakeholders due to distance teaching and learning.

We considered this phenomenon's complexity; thus, the mixed-method quantitative-qualitative approach played a significant role. The mixed-method was implemented to identify the study's participants and later "develop questionnaires and conceptual models" [15]. A qualitative approach generated a deeper insight into the phenomena and a

contextual understanding of challenges faced by the stakeholders. Such validation was achieved by cross-examining the data from two diverse yet complementary angles: cluster analysis and theme analysis. Moreover, the study's initial phase further validated data derived from the quantitative component [16–18].

2.2 Data collection

The survey's data aimed to understand the pandemic phenomena and how its disruption affected the education system. This data was later used and validated in the next phase of the longitudinal study - the semi-structured interviews. The sample's scope of the three education stakeholder groups aimed to grant a comprehensive insight into this specific period and the arising constraints. Afterwards, a purposeful sampling method was used, where six individuals were selected to be interviewed due to their singular and meaningful experiences of the phenomenon of interest and their connection with the collective occurrences [19].

The study's recruitment focused on the 8th grade. The sample was selected using a cluster sampling among individuals who shared common characteristics and experiences to be interviewed multiple times through the month of April. That is, the selection of deviant cases enables the registration of a diverse set of perspectives "that have emerged in adapting to different conditions" [15] on the same phenomenon. The data was retrieved from this sampling technique, allowing us to record and examine individual or collective patterns of the participants' diversified experiences over this transitional period [15, 16, 20].

Survey. The longitudinal study started with the survey's design and was composed of three questionnaires aimed at three stakeholder groups (N=215) living in Portugal. To comply with the health authorities' safety measures, namely the social distancing, we chose to post the questionnaires on specific Facebook channels between the 1st and the 14th of April 2020. These Facebook groups, managed by and/or attended by teachers (87 249 members, collectively) or parents (12 390 members, collectively), granted valuable insights into the methods and processes taken to mitigate the Covid-19 disruption on education. For the students, it was used the snowball technique where was asked three students to fill out the survey and referred it to their friends and colleagues, thus increasing the sample size [21]. We probed the respondents' attitudes, preparedness, and employment of ICTs during the transition from a regular school setting to an online one. Additionally, the questionnaires composed of 40 questions, on average, consisted of multiple-choice and further specific open-ended questions to understand the respondent's distinct observations and experiences amid the pandemic that would be used to design the 5-week-long interviews with the same stakeholder group [15, 16, 19]. 79% of inquired subjects were teachers, 4.7% students, and 16.3% parents.

Interviews. This study also contemplated an interview sample (N=6), see Table 1, to generate diversified insight into the teaching and learning constraints arising from the use of ICTs during the pandemic.

Table 1. Interview's sample detailed information.

ID	Stakeholders	Age	Gender	Sector	Area's typology	Socioeconomic background
T1	Teacher	48	Male	Public school	Urban	Low-poverty area
T2	Teacher	43	Female	Public school	Rural	High-poverty area
S1	Student	14	Male	Private school	Urban	Low-poverty area
S2	Student	15	Male	Public school	Semi-Urban	High-poverty area
P1	Parent	41	Female	Private school	Urban	Low-poverty area
P2	Parent	42	Female	Public school	Semi-Urban	High-poverty area

The use of convenience and purposeful methods, combined with the extreme user method [22], determined the selection of two 8th grade teachers (T1, T2), two 8th grade students (S1, S2), and two parents with children enrolled in the 8th grade (P1, P2) [19]. The sample tried to gather contrasting perspectives by including participants from the public and private school sectors, dispersed geographically throughout three cities (rural and urban areas), from the same region, with comparatively different household incomes and diverse academic and employment profiles. Despite the small sample, this diversified sampling allowed us to record and examine individual and collective patterns from the participants' varied perspectives. The selection of deviant cases made it possible to record comprehensive insights that emerged from the adjustment to the various issues that emerged when schools were closed. [16, 23].

We adopted a semi-structured interview method due to its flexibility, enabling a balanced way to obtain information evoked by the interviewee. It also helped to create an iterative synergy between the interviewer and interviewee, an "attempt(s) to understand the world from the subjects" [24] point of view and their experiences [15, 25–28]. The longitudinal study was defined according to Morse and Niehaus [29], in which the data "is gathered from the same subjects repeatedly over a period of time". So, the 6 participants were interviewed once a week for five weeks, comprehending April and May of 2020, generating 30 interviews. This process occurred by Zoom or telephone for an estimated 13 to 21 minutes.

The semi-structured interviews were designed in response to data collated in the survey, which purposefully guided conversations. The more significant number of teachers' survey responses allowed a more precise direction in the interviews' design, whereas the students' and parents' initial interviews were more exploratory. The interviews consisted of a list of questions and follow-up ones to probe interviewees' pertinent remarks. Upon recording, transcribing and the responses' examination, a new set of questions arose, correlated to interviewees' previous comments and the quantitative data retrieved from the survey, thus clearing or reinforcing some issues and unfolding new ones [25].

2.3 Data Analysis Method

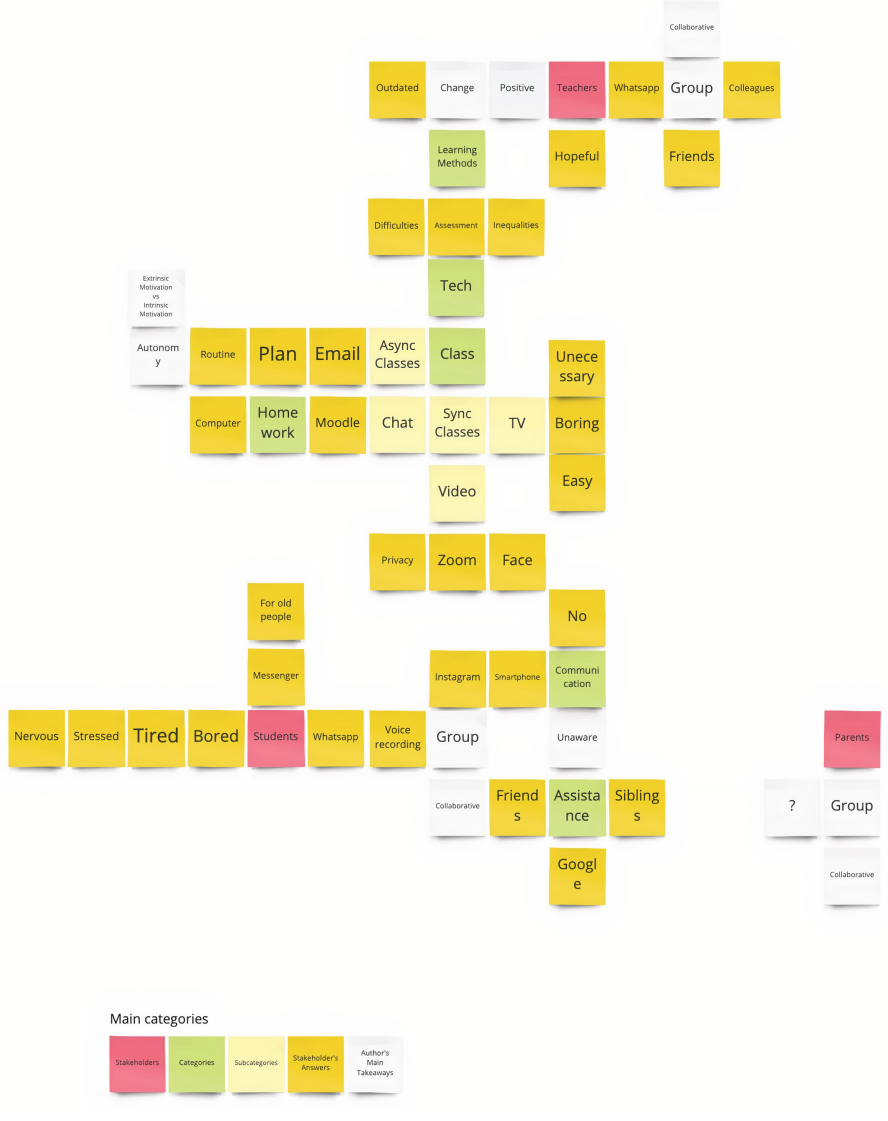

Fig. 1. Longitudinal interviews' cluster analysis

Survey. The 30 recorded interviews were transcribed, analysed and divided into 11 categories placed in one spreadsheet with a specific colour. Excerpts from interviews were added to each sheet and coded into 11 colour-coordinated categories: (i) feelings

& perceptions; (ii) homework; (iii) student's assistance; (iv) group activities; (v) classes's structure; (vi) learning methods; (vii) technology; (viii) social media; (ix) communication; (x) institutional information and (xi) tele school. We added excerpts of transcribed interviews to each sheet, according to a respective category and relative to each stakeholder (teacher, student, or parent), week (1 to 5) and individual (1 or 2).

Cluster analysis. A subsequent cluster analysis (Figure 1) summarises excerpts from transcripts, feature coding, and words that encapsulated their overall meaning or feeling. The resulting 33 words were later placed individually on digital sticky notes, using Miro3, an online collaborative whiteboard visual platform. The notes are colour-coded to give an overview or relation between stakeholders and their statements. We placed codes relative to categories where most codes emerged. We also identified the three stakeholder groups on dark pink notes; the categories or feature codings' codes are green, the subcategories are light yellow, the 33 words are dark yellow, and the authors" main takeaways are white. This method helps assess data and reveal "the motives of participants for their actions and the reasons behind counterintuitive finding" [30]. The visual data representation simplifies and gives a discernible overview of the material and the emerging themes.

Theme analysis. A theme analysis was also conducted to cross-examine the "individuals' perceptions, feelings, knowledge and behaviour" [31]. Such research was performed using Lucidchart[4] and outlined the overall impressions of the codes found in the feature coding. The digital sticky notes with the general impressions were used as guidance to reach the three main themes that arose according to the data retrieved from the feature coding: "Education duties", "Technologies", and "Communication". Other themes emerged from the previous ones, thus forming a new sub-theme layer.

3 Findings

3.1 Stakeholders' readiness and learning continuity amid the pandemic

We observed general unpreparedness for distance learning's continuity in response to sudden disruption manifested in a lack of methodological knowledge and tools for DE. According to the surveys' respondents, the scarce resources for DE of 64.7% of teachers and 34.3% of households demonstrate uneven fairness emphasised by the inexistent DE training of 87.6% of the surveys' respondents, acknowledged by T2 and P2. The lack of DE teacher and student training is also a pressing issue for 87.6% of the surveyed respondents. This information is a natural conclusion of data that seems to indicate that despite the support to implement technical mediums in K-12 schools, most teachers maintain the use of technology to a minimum. Its scarce application is limited to tech introduction, keyboarding and basic computer programming, which does not take full advantage of the available technology to support the students' learning [32–34].

3 https://miro.com/

4 https://www.lucidchart.com/

All stakeholder groups recognised the lack of DE preparedness as a significant gap. According to 70% of the surveyed students and 54.3% of the parents, the teachers' lack of knowledge about DE methods and their implementation led to unclear or non-existent communication and instruction for students who ultimately relied on online search engines and online sources. In response, many of those surveyed had to seek information online through social media groups, where many were already present. Reliance on social media groups for support was particularly prominent among more senior teachers who felt they were facing uncharted territory, especially video conferencing tools, such as Microsoft Teams or Zoom (T1, T2, S1). Generally, the older teachers preferred Facebook Messenger and WhatsApp when seeking support amongst their peers, whilst students selected WhatsApp and Instagram. The survey data indicates that 80% of the parents who belonged to a WhatsApp group would visit the group more than five times a week to seek more information to support their children. 50% of these parents' interactions are about their children's homework, 16.7% about remote learning, 16.7% about their expanded role in their children's education, and 16.7% about how to submit their students' tasks into the online platform. This information proved valuable for 80% of the students' parents, who claimed that teachers did not always answer their children's questions raised during DE classes. As demonstrated by the quantitative data, this issue is more pressing for 20% of students who claim a lack of support after class. On the other hand, those who felt supported stated that teachers had an essential role in ensuring learning continuity (66.7%), followed by their parents (55.6%), classmates (44.4%), or siblings (11.1%).

3.2 Students' learning loss and variability

Once school closures resumed, still in a remote context, teachers increased student workload to address educational needs and ensure learning continuity. Although 78.2% of the surveyed teachers believed that this was an adequate number of tasks sent to the students, 70% of the surveyed students disagreed with this approach and reported that they often felt overwhelmed, an opinion shared by their parents. The number of tasks sent to students after the schools' closure were also considered overwhelming by S1, P1, and S2. The teachers observed a qualitative decrease in students' responses and a decline in-class participation. As a result, there was a reduction in homework as soon as teachers realised that students were not meeting the expectations set by a high volume of tasks.

Student participation in synchronous or asynchronous classes also decreased because "there's no comparison between expressing verbally, and clearing a student's doubts using a chat, for students to see, when or if they see it" (T2). In addition to the insufficient learning, teachers observed the importance of parent assistance, but some "will not support the student's needs, and many other needs" (T2, S2, P2), thus confirming the claim of 57,1% of the surveyed parents who said they could not assist their children's academic needs. This issue is especially alarming for students who lack a supportive network and often do not have someone who "can step in as tutors or monitor kids without strong self-learning skill"[35], therefore increasing previous inequalities and learning variability amongst the student population [7].

3.3 The weakest link

The retrieved data identified strong connections between clusters in the cluster analysis, as demonstrated in Figure 1. The "students'" and "teachers'" clusters are connected through technological tools such as "computer", "Zoom", "email", and social media platforms, for example, now incorporated into the new "learning methods" used in the DE context. That is, such tools had a predominant role in the stakeholders' learning and teaching process. Upon further examination, the importance, use, and knowledge of DE's technical mediums are evident, as well as the collaborative dimension implied in their use. This dimension is acknowledged in the sticky note "Group", highlighting the importance of peers, friends, and acquaintances in clarifying doubts resulting from DE context.

Additionally, students and parents believe that the collaborative nature of technology was fundamental to the student's understanding of the concepts taught on the online platforms and to the many limitations experienced by parents in their new role of teaching aids. Moreover, the parent's cluster is left detached and unresponsive to the other clusters, reflecting the parents' lack of engagement and understanding. Some parents embraced their new role in their children's education; however, many experienced frustrations due to the DE setting (P1, P2, S2). Finally, the question mark, visible in the parent's cluster in Figure 1, demonstrates the lack of contextual awareness and knowledge that inhibits parents' ability to participate and support their children during DE.

4 Design Implications

Human-Computer Interaction (HCI) research is continuously studying how to connect people over distance using interactive digital technology, which in the Covid-19 pandemic has an added purpose. Not just in the light of the remoteness by itself but as the only means to connect, possibly for an unforeseeable time, the whole education system. It is fundamental to provide "a rich experience to all learners who are now without 'traditional' teachers standing beside them in classes" [36]. Instead of relying solely on text, interactive technological devices may enable several resonant types of answers to a problem, thus fostering creative thinking. ICT tools can be aided with tangible materials, compelling the students to rely on other learning tools than their electronic devices.

From the previous results presented in Findings, we can conclude that the ICTs' general acceptance does not necessarily mean that their implementation and use reassure the learning continuity's success. The need for a flexible response due to the pandemic's uncertainty and the education stakeholders' extensive requirements should be recognised and further addressed. Moreover, the collaborative reflection expressed by the stakeholders indicated the need for a redesign of the existing solutions (T1, S1) and the expansion of more technological mediums to enable interactions among the stakeholders that were part of this study. A set of design implications was developed after the longitudinal mixed-methods study analysis [37], which was divided into three groups: a) levelling the playfield with an assessment and equitable distribution of resources (5

design implications); b) managing the learning experience that emphasises the academic and bureaucratic systematisation to increase effectiveness and participation (8 design implications); c) communication and collaboration efforts must be implemented to extend an effective interaction for varied purposes (8 design implications). These solutions seek to answer students' pedagogical needs (T1, T2, S1, S2) and reduce the teachers' and families' struggle to help their children with their assignments and homework (S2, P2).

4.1 Levelling the playing field

An important category that could be used to generate design implications consists mainly of technology-driven solutions (T1, T2, S1, S2, P1, P2). Implementing the set solutions might not be homogeneous throughout the schools or regions, and "there will always be injustices" (T2). Some families already possess a device (tablet, laptop, or pc), but it is essential to know if that device is shared or not, among one or more siblings, for example.

Ensure technological equity. It is fundamental to understand the shortcomings of school communities to ensure resources' equity (T1, T2, S1, S2, P1, P2). This assessment could be executed using surveys (by any means available) to teachers and families to know who will need devices and bandwidth.

Resources' evaluation. An estimate of all available digital resources is required, as well as the promotion and optimization of their use for mobile devices when a laptop or computers are not available.

Increment of usability. Increase the interactivity of the resources of the digital platforms in which the user would be notified in a timely manner, in colour graded manner, according to the type of material available like homework, grades, or information (T1, T2, S1, P1).

Technological instruction. Training must be provided to tutors and students, in the implemented technological solutions and the future ones, continuously and in different formats such as tutorial videos or still images, for example.

Technological support. Educative institutions (schools or governments) could aid teachers, students, and parents with consistent and continual tech support to the digital tools, which should be limited to avoid the occurrence of confusion. Therefore, a tech support team could be created to assist the school community, providing help in several formats, such as telephone, videos, still images, step-by-step guide text, etc.

4.2 Managing the learning experience

The qualitative data analysis also concludes the need for a protocol in which a schedule is organised for classes, homework deliveries, discussions, and/or interactions.

Participatory management. The school community could be encouraged to make recommendations or suggestions in an open and participatory manner. The community's involvement will serve to understand and consider everybody's points of view and set expectations.

Class management. A class protocol could include 45 minutes of extended classes to promote students' participation in the last 15 minutes of class (T1, S1). As well as develop students' presentation content or homework to value their synthesis and public speaking (P1, P2, S1, P1). This extended time could serve students to comment on each other's work by giving and taking constructive feedback and insightful suggestions.

Class participation. Videoconference classes proved to be a matter of deep discussions about its pertinence and safety. According to one participant, synchronous videoconference classes facilitate "proximity to students, for one side, while on the other, some students will always be harmed because their familiar environment is not conducive to those types of classes" (T2). There is a need for a "certain type of isolation for them to focus on those types of classes" (T2), yet it seems to be the best approach because it "draws more of their attention than being there chatting" (P2).

Establishing homework's guidelines. A protocol should be established for assigned tasks and homework where a work-sheet plan could be sent regularly (weekly or bi-weekly), so the school community can organise their schedule. This will allow the "parents to be able to support their children and to facilitate the student's organisation" (T2) as well as imbue an extended sense of responsibility, autonomy, and proactivity.

Independent learning. Although student's autonomy can be nurtured and promoted, "sometimes it's good to be pushed to improve" (S1), and consistent deadlines seem to improve student's responses (S1, S2, P1, P2). An organisation tool could be established for students if they choose to follow.

Homework efficiency. Online learning should not overwhelm students, so the amount of homework should be divided into smaller parts with clear objectives. Teachers could take advantage of the interactive multimedia to support other activities like watching videos/movies/documentaries or exploring cities and/or museums virtually to create a more engaging learning experience (T1).

Teacher's feedback. Teachers could provide feedback on the previous homework in the next assignment plan, so students are aware of their learning process. Moreover, the feedback could be immediate through online collaborative documents, thus motivating the students to continue their learning.

4.3 Communication and Collaboration

A pertinent claim expressed by participants (T1, T2, P1, P2) was the timely and consistent access to information. Uncertainty could be alleviated quickly with more precise, concise, and constant communication among the school community, especially amid disruptive events. To avoid confusion and mistrust, teachers, parents, and students could have access to various levels of procedures and frequently asked questions.

Data anytime, anywhere. Digitising pertinent information, such as the school communities' contact, is preferable to facilitate communication. Maintaining an up-to-date source of information is crucial to optimise time and resources, as well as "prevent confusion and miscommunication" (T1).

Group communication. It is essential to endorse students, parents and teachers' associations and the creation of groups among them on a platform chosen by them. The set group might be used to "clear doubts, as well as to inform each other of new training" (T2). But a set of contact standards and conduct norms among stakeholders must be developed to avoid miscommunication and inappropriate remarks or interactions (S1, P1). And while teachers can seek their colleagues for emotional, psychological, or theoretical support, they can also promote closer interaction among students.

Teacher/Students' communication. A contact group could be created on a safe and more consensual platform, so trust can be built and establish an open line of communication. It is important to understand students' favourite options and forms of communication, either text or voice message (T1).

Students' open, collaborative communication. Although students claim to resort to search engines like Google to understand some concepts to solve their homework, a crossed communication platform between students from different grades can also be created. The older students could help the younger ones, thus mitigating the deficient learning that 80% of inquired students, 84.1% of teachers and 51% of parents claim to exist. Moreover, according to the same surveys, 50% of the parents resorted to social media groups to understand how to clear their children's doubts. This tool could also be promoted to forge fellowship among students and promote a healthy and amicable school environment.

Open, collaborative teaching system. The remote and collaborative nature of interactive digital tools could also be deployed in a teaching community that can answer students' questions on an individual level. It also could mitigate the lack of support some students have at home, namely the 57,1% of parents who claim they are not able to fully clear their children's doubts (S2, P2). It is especially alarming to the students without a supportive network without someone who can adequately help them. The solution should be comprehensive so students with learning impairments are also addressed in these precarious circumstances. Moreover, the instruction in a human-centred manner, as praised by the UN, would therefore lead to a humanised learning environment.

Students' closed collaborative communication. The collaborative element mentioned in *"Student's open, collaborative communication"* could also be lightened by creating group studies and enhancing the number of group projects assigned to students who will use collaborative digital tools to accomplish it (S1, S2).

Students' low-tech communication. A group study may be created to tackle the low technological accessibilities from one or more group members. A protocol should be developed in which a provided worksheet could be shared with the student with no technological resources by resorting to postal services, like a peer-to-peer communication, via low-tech solution, "so that kids with no internet can feel like they belong" [34].

PenPal Project. A PenPal might be assigned to one student or a group of students who would help each other through platforms designed for that purpose. The postal services might also be used for it by supporting a distinctive way to start new kinships and friendships - nationally or internationally. The students would achieve new academic and personal capabilities and skills, such as a new language, thus broadening their horizons and making new connections.

5 Conclusions

In this paper, we presented design implications developed through a longitudinal mixed-method study with three stakeholder groups of the educational community. The data retrieved from this study indicate that education progressed, amid the pandemic, via interactive communication platforms and social media. The teaching and learning progression happened regardless of the school community's lack of readiness, ICT training and resources in the transition to DE, causing apprehension and anxiety among the school community. Additionally, some parents' inability to properly assist their children's learning needs leading to a series of issues that the school community tried to solve collaboratively within specific online social media groups. The issues found in this study, concealed in the pre-Covid-19 pandemic, were aggravated, revealing severe inequities in education and knowledge access.

It was observed in this study a deeper understanding and acceptance of the interactive digital mediums in education, especially in the DE context. In accordance with data retrieved from this analysis, we also concluded a greater awareness of the students' specific needs. The pandemic's aggravation's repercussions on the educational system and its inability to respond accordingly were also verified. We conclude, as well, with the awareness of the student's specific needs.

The preliminary findings and the design implications may derive avenues for future design and improvements on the existing ones. Our goal is to further assess the dataset and create a thorough design toolkit to simplify the school community interactions via interactive technologies and/or the development of blended solutions that comprehend the analogue technology as well in order to attend to the students' diverse set of needs.

6 Limitations and Future Work

This study tried to extend the scope of research by looking for a wider variety of participants. Yet, the Covid-19 pandemic's constraints did not allow to accommodate more individuals in the longitudinal mixed-method study. The anecdotal sample's limitation is acknowledged, and some findings could be seen as tentative interpretations; however, the emerging data provide a broad view of the stakeholders' varied experiences amid the F2F transition to the DE setting, contextualised by relevant literature and prior studies. It is also recognised the absence of senior teachers from the sample due to the pervasive use of ICT tools as a primary source of interaction with it. According to the presented data, these teachers, who were more struggling than others, might lack the presence in this study's considerations; thus, it may have biased results. Additionally, we conducted this study according to a convergence of geographical and pandemic settings. Therefore, the insights we provide in this study might be directly correlated to a specific context not suitable for other contexts.

In order to grant a more comprehensive and augmented understanding of this matter, future work may encompass more individuals and more extensive groups of stakeholders of diverse ages and educational, geographic and cultural backgrounds. Additionally, it would also be beneficial to analyse these subjects' perceptions and experiences on a fully developed interactive system in the long term and how such examination relates to this study. The long-term analysis could examine the impact of the learning environment and the personalised teaching mediated by this system on the students' academic achievements, namely their evolution in the subject(s) they had more difficulties with.

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