The Effects of the Covid-19 Pandemic on Italian Learning Ecosystems: the School Teachers' Perspective at the steady state

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Abstract. This study is one of the first investigations conducted within the Italian school system to capture teachers' perspective, experiences and perceptions about the impact of the COVID-19 pandemic on school education. It was performed two months after the beginning of lockdown, when online teaching and learning processes were fully in place and had reached a steady state. The paper reports a descriptive analysis together with a network analysis, and the search for causal relationships among the variables that have been investigated. Generally, respondents reported that the reactions of educational institutions and individual teachers were satisfactory, preventing the collapse of the education system in spite of loss of contact with 6-10% of the student population and a significant teacher workload increase that posed individual time management challenges. Although teachers tended to adopt teaching strategies that reproduced standard classroom dynamics, the possibility of operating in this comfort zone generated a positive feeling about using technologies, a perception of increased digital skills mastery and a change in mindset about educational processes. In turn, this led to an increase in the perceived sustainability of online education, with about a third of the teachers expressing the wish to adopt a blended configuration for future teaching activities. Almost all participants recognized the significance of a digital pedagogy and the need to include it in the training curricula to prepare future teachers.

Keywords: COVID-19 pandemic, online learning, emergency remote education (ERE), educational ecosystem reactivity, school teachers, educational innovation, descriptive analysis, causal discovery

1. Introduction

In the first half of 2020, almost all educational ecosystems (including those centred on schools, universities, private centres, etc.) around the globe were forced to cancel face-to-face (f2f) classes as a non-pharmaceutical intervention to contain the spread of the COVID-19 pandemic [1]. In these circumstances, shifting courses from f2f to online was a policy response mandated by the compelling need to keep teachers, staff, students and society at large as safe as possible in the face of a public health

emergency whose spread was unexpected, exceptionally fast and poorly understood. In April 2020, the lockdown was almost complete, affecting more than 1.5 billion students, i.e. 90% of the worldwide student population in almost 200 countries [2]. Mass school closure was simply a quick fix adopted in 'less-than-ideal circumstances' [3]. The pressing haste with which many educational institutions moved to online education may have prevented them from harnessing its strengths and dealing with its limitations. This is probably going to be a popular theme of investigation for scholars for several years to come. The public debate about the way schools (as well as universities) reacted to the emergency has proliferated in the grey literature, in the mass media and on social networks (e.g., [4, 15, 16]). "The temptation to compare online learning to face-to-face instruction in these circumstances" [3] has brought about negative considerations along the lines that online learning is no substitute for the 'real thing.' At the same time, it has also generated (perhaps over-) optimistic expectations that, after this "great online learning experiment" [5] is over, our educational institutions and their teaching staff will be readier than ever to move to online or blended learning once and for all. In any case, such a dramatic emergency can be regarded as a catalyst for change and an opportunity to reflect on the nature of educational ecosystems (places, processes, contents, competences, etc.) [6-8]. Among the positive outcomes, some authors [16, 18] refer to increased teacher awareness of digital technology's affordances for learning, including better opportunities for providing personalised feedback, more intensive sharing of challenges and solutions adopted, and consequent participation in professional communities not to mention all the pre-COVID research results that highlight the affordances of online learning [19]. The pandemic has also shed light on some undesirable effects of Emergency Remote Education (ERE) that have been seen on a global scale, primarily inequalities in access to education due to social, economic, personal and family conditions. Access inequalities, in fact, are not only due to lack of digital connectivity: the emergency has acted as litmus paper for access problems due to social, educational, health and digital equipment inequalities [9]. In addition, virtual contact is often seen merely as a surrogate for direct social contact between teachers and students, especially for young children [15,16]. The need for parental support has increased, particularly for students with poor self-regulated learning skills, a factor which in turn reinforces inequalities [18]. Online fatigue and emotional wellbeing of all the actors concerned are also mentioned by many authors. The whole experience, and the evidence emerging from it, calls for informed decisions concerning appropriate educational policies [6-9]. Such policies should be aimed at not only improving readiness and effectiveness in coping with possible future emergencies in a (more) sustainable manner [18], but also preparing teachers and students alike to harness the full potential of smart learning environments.

As we write (July 2020), the scientific literature and empirical research evidence about the impact of the Covid-19 emergency on schools are still limited, and for understandable reasons they provide a rather scattered picture of the situation. Surveys addressing teachers have been conducted in India [14], Vietnam [10] and Massachusetts [20], with quite different aims. In particular, the second study reports

on a survey conducted among Vietnamese teachers in conditions very similar to the present work: i.e. carried out over a relatively brief period of time about two months after the national school shutdown. Although surveys are by far the most common research method adopted to study ERE, other methods have also been used to collect data about the challenges teachers faced during the emergency. For example, Trust and colleagues [18] analysed Twitter Hashtags to understand how teachers built collective knowledge, sought emotional support, and designed their teaching by interacting with others in professional communities. This study suggests that the emergency situation may have encouraged teachers to adopt participatory behaviours, in contrast with previous studies maintaining that content sharing and community building are usually neglected by teachers [39,40]. Last but not least, a few studies that investigated similar situations occurring in the past (such as the 2003 SARS epidemic and the 2009 school closures for influenza pandemic) provide evidence of the non-uniqueness of this situation [11,12, 21].

It will only be in the coming months and years that scholarship will be able to fully analyse the educational, policy and societal implications of this emergency. Nonetheless, we believe that this study is timely in analysing the outcomes of a survey intended to provide a broad picture concerning a range of variables related to school settings, operational conditions, educational activities carried out during the pandemic, teachers' perceptions about the impact of this unprecedented experience on their work and their mindset with respect to technologies and their future commitment to online learning.

The study is intended to provide an early contribution to the understanding of how school education unfolded during the pandemic, an historical documentation, a point of reference for similar studies in the future and, hopefully, a first step towards collective reflection on possible avenues of development for our educational system build on informed policy decision making.

2. Experimental setting

2.1 Questionnaire

The survey was carried out by means of a three-section questionnaire presenting a total of 80 items. Section I comprises six socio-biographical background items (gender, age, school level, school curriculum and teaching subject, geographical location). Section II presents 43 items (23 questions requiring a multiple choice or numerical answer and 20 open questions or requests for explanatory comments). This section focuses on respondents' perceptions about how the learning ecosystem responded to the pandemic and the operating conditions at what we consider the "steady state" of lockdown measures (i.e. after about two months from the beginning of the schools' lockdown). Section III comprises 31 items (14 questions requiring a multiple choice or numerical answer and 17 open questions or requests for

explanatory comments). This section these investigate any changes in teachers' opinions about technologies and online learning and their expectations for the future. The complete questionnaire is available at [42].
In this paper we analyse respondents' answers with the aim of providing a snapshot of the situation in Italy and scrutinize teachers' perceptions about the capability of learning ecosystems to react, the operational conditions, and the type of educational activities carried out (variables listed in Table 1). We also investigate which of these variables might have modified their perception of technologies and expectations for the future (variables listed in Table 2).

This is one of the first nationwide studies to investigate the effects of the pandemic on teachers' perceptions of online learning. Our study is grounded on previous experiences – descriptive investigations - conducted by one of the authors with a sample of university students [8] and respondents from a pair of high schools [13]. Thus, the need for a bespoke questionnaire and a research method intended to shed light on the network of relationships that connect the variables listed in Tables 1 and 2.

2.2 Participants

The participants were contacted by email or via announcements on social media; Facebook turned out to be the most effective dissemination channel. We posted the call for participation in more than 30 teacher groups on Facebook, attracting a total of about 60,000 (non-unique) responses. Since our goal was to produce a snapshot of the Italian situation about two months after the introduction of the school lockdown (March 5th, 2020), the survey was only open from May 13th, 2020 to May 24th, 2020. Before closing the survey we checked that the sample was representative of the Italian teacher population. The survey was completed by 336 teachers (306 females, 29 males, 1 non-binary) employed in primary (142), lower secondary (84) or upper secondary (110) schools. In terms of macro-regional area distribution, 142 were from North Italy, 97 from Central Italy, and 113 from South Italy and the islands.

The sample vs entire population comparison revealed slight imbalances in terms of gender (91% females in the sample, compared to 83% in the target population, $p < .001$), and geographical distribution (respectively 38%, 29% and 34% for North, Centre, and South Italy compared to 40%, 22%, and 38% for the entire population [23]; $p = .009$). However, the sample appeared to be representative of the mean population age (49.10 vs 48.90, $p = .684$) [22] and school level taught ($p = .118$). School level and teacher gender were associated ($\chi^2(2) = 18.89$, $p < .001$), as there were significantly more males employed in upper secondary schools (18.2% of upper secondary school teachers vs. 4.7% for lower secondary and 3.5% for primary school). Geographical zone was associated neither with gender ($\chi^2(2) = 1.06$, $p = .590$) nor school level ($\chi^2(4) = 3.46$, $p = .484$).

As an additional control we measured the possible fatigue effect induced by the length of the questionnaire. This turned out to be very low, with less than 5% of respondents skipping the multiple choice and numerical-answer questions, even towards the end of the survey (see Fig. 1A).

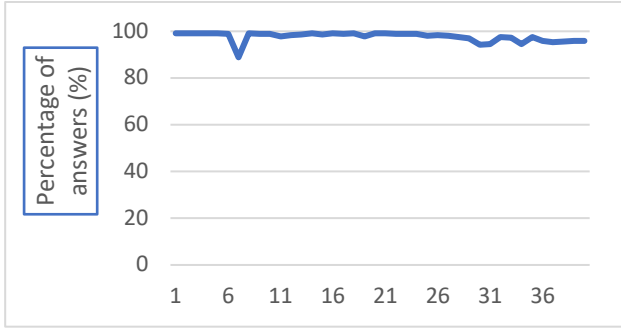


Fig. 1. Percentage of non-blank responses to multiple choices and quantitative questions as a function of the question ID.

3. Results

In order to explore teachers' feelings and opinions as well as the complex network of relationships that connect the variables investigated in sections II and III of the questionnaire, we pursued multiple strategies. First, we carried out descriptive and univariate analyses (Tables 1 and 2), exploring the observed distributions of the variables considered in this section (section 3.1). Then we fitted multiple linear regression models to establish which, if any, variables would best predict key outcomes (section 3.2.1). Subsequently, to obtain a bird's-eye view of the variables' relations, we employed the paradigm of network analysis for visualizing the partialized correlations between variables (section 3.2.2) and infer the direction of causality for some of these associations (section 3.2.3).

3.1 Descriptive and univariate analyses

Technological context. More than 92% of the teachers report having needed less than two weeks to adapt/get used to online education. This confirms that, with the exclusion of the 8% that didn't feel comfortable with it, for all the rest the operational conditions photographed by the survey should be considered as "steady state". This conclusion is in line with results of a study [27] that surveyed primary schools principals in Ireland and compared their responses respectively two weeks and two months after the school lockdown was imposed.

More than 86% of the survey respondents in the Italian study used a laptop to connect online and carry out their teaching activities. This is not surprising, since the lockdown has strongly reduced personal mobility and thus the specific usefulness of smartphones (see also ref. [8]); nevertheless, 40% of the teachers still used these devices for teaching purposes, possibly in parallel with their laptops. About 12% of the respondents used their smartphone to connect to the internet as access point too. Almost 35% of teachers used a tablet and about 22% a desktop computer. Less than half of the teachers (44%) had broadband or ultra-broadband access to the internet,

36% accessed using an ADSL connection, while the rest relied on mobile/satellite data connection or other forms on internet connectivity. Twelve percent lamented the lack of or limited availability of devices suitable for carrying out online activities; more than 36% complained about insufficient bandwidth and 8% lamented the limited traffic allowance available to them from their internet providers. According to the teachers, their students experienced similar issues, limiting participation in educational activities to some degree or even completely. Ten percent of the teachers stated that they lost contact with 20% or more of their students, 20% lost contact with 5% to 20%, 45% lost the contact with less than 5% of the students, while about 25% managed to stay in contact with everyone.

These proportions are not dependent on school level ($\chi^2(10) = 12.70, p = .241$). From these data, taking the lower and upper border of each class, one can estimate an average dispersion ranging between 6% and 10%, which corresponds, nationwide, to 400K-670K students.

We may reasonably expect that such "infrastructural" criticalities may have affected the quality of education and caused, in some cases, a significant divide. Although documented in less detail, similar and more serious difficulties were also reported in [10] and especially in [14].

In the following, Table 1 reports the data collected through the items of section II of the questionnaire, concerning teachers' perceptions about the capability of the educational ecosystems to react, the operational conditions and the features of the educational activities carried out. A 10 point Likert-like scale (1-10) was used unless otherwise indicated. The last column of the table reports results of the t-test computed to identify any significant difference between school levels.

Table 2 reports the data collected through section III of the survey, i.e. teachers' perceptions about their experience with ERE and their expectations for the future, as well as t-test results concerning differences between school levels. A 10 point Likert-like scale (1-10) was used.

Table 1. Survey Section II results: teachers' perceptions about reactivity and operational conditions of the educational ecosystems, and features of the educational activities carried out.

Variable	**Average**	**t-test**	**Difference between school levels**
School Readiness to switch to online education (SR)	M = 6.23 [5.98, 6.48]	$t(335) = 5.83, p < .001$, *Cohen's d* = .32	$F(2, 333) = 3.45, p = .032, R^2 = .01$; higher for upper secondary
Technological Adequacy of Online Environments (TAOE)	M = 6.36 [6.10, 6.62],	$t(334) = 6.47, p < .001$, *Cohen's d* = .35	$F(2, 332) = 1.62, p = .200, R^2 < .01$
Digital Safety of technological environments (DS)	M = 6.52 [6.26, 6.78]	$t(330) = 7.58, p < .001$, *Cohen's d* = .42	$F(2, 328) = 2.24, p = .108, R^2 < .01$
Teachers' Technological Readiness (TTR)	M = 5.93 [5.72, 6.14]	$t(332) = 4.06, p < .001$, *Cohen's d* = .22	$F(2, 330) = 2.79, p = .063, R^2 = .01$
Teachers' Pedagogical Readiness (TPR)	M = 5.85 [5.65, 6.05]	$t(333) = 3.41, p < .001$, *Cohen's d* = .19	$F(2, 331) = 2.89, p = .057, R^2 = .01$

Workload Increase (WI) %, tested against a baseline of 0	M = .65 [.63, .68]	$t(335) = 45.2$, $p < .001$, *Cohen's d* = 2.47	$F(2, 333) = 5.35$, $p = .005$, $R^2 = .03$, lower for primary schools
Teachers' Time Management Capacity (TTMC) (scale -5, +5)	M = -.43 [-.74, -.12]	$t(335) = -2.75$, $p = .006$, *Cohen's d* = .15	$F(2, 333) = 1.01$, $p = .364$, $R^2 < .01$
Students' Time Management Capacity (STMC) (scale -5, +5)	M = -.67 [-.95, -.40]	$t(331) = -4.82$, $p < .001$, *Cohen's d* = .26	$F(2, 329) = 5.00$, $p = .007$, $R^2 = .02$, lower for primary schools, higher for upper secondary
Educational Activities performed: balance Lecture-Discussion (EALD) (scale -5, +5)	M = .37 [.13, .60]	$t(335) = 3.11$, $p = .002$, *Cohen's d* = .17	$F(2, 333) = 4.37$, $p = .013$, $R^2 = .02$, higher for primary schools
Educational Activities performed: balance Transmissive-Interactive (EATI) (scale -5, +5)	M = 1.06 [.81, 1.31]	$t(334) = 8.43$, $p < .001$, *Cohen's d* = .46	$F(2, 332) = 2.05$, $p = .130$, $R^2 < .01$
Educational Activities performed: balance Asynchronous-Synchronous (EAAS) (scale -5, +5)	M = .85 [.58, 1.12]	$t(334) = 6.22$, $p = .002$, *Cohen's d* = .34	$F(2, 332) = 7.61$, $p < .001$, $R^2 = .04$, higher for upper secondary
Educational Activities performed: balance Individual-Collaborative (EAIC) (scale -5, +5)	M = -.36 [-.67, -.05]	$t(334) = -2.26$, $p = .024$, *Cohen's d* = .12	$F(2, 332) = .23$, $p = .796$, $R^2 < .01$
Reproducibility of F2F Classroom Dynamics (RCD)	M = 5.32 [5.08, 5.57]	$t(331) = 5.32$, $p = .151$, *Cohen's d* = .08	$F(2, 329) = 6.14$, $p = .002$, $R^2 = .03$, higher for upper secondary

Table 2. Survey Section III results: teachers' perceptions about technologies and their expectations for the future.

Variable	**Average**	**t-test**	**Difference between school levels**
Sustainability of Online Education (SOE)	M = 5.17 [4.93, 5.42]	$t(329) = -2.63$, $p = .009$, *Cohen's d* = .14	$F(2, 327) = .41$, $p = .664$, $R^2 < .01$
Change in the Idea of Educational Experience (CIEE)	M = 5.18 [4.89, 5.47]	$t(319) = -2.17$, $p = .030$, *Cohen's d* = .12	$F(2, 317) = 1.39$, $p = .250$, $R^2 < .01$
Improvement in the Attitude towards Technologies (IAT)	M = 6.30 [6.01, 6.59]	$t(329) = 5.45$, $p < .001$, *Cohen's d* = .30	$F(2, 327) = 5.06$, $p = .007$, $R^2 = .02$, higher for primary school, lower for upper secondary

Improvement in Technological Skills (ITS)	M = 6.88 [6.63, 7.12]	$t(328) = 10.85$, $p < .001$, *Cohen's d* = .60	$F(2, 326) = 7.19$, $p < .001$, $R^2 = .03$, higher for primary school, lower for upper secondary
Intention to Work in Online Learning (IWOL)	M = 5.14 [4.83, 5.46]	$t(324) = -2.24$, $p = .026$, *Cohen's d* = .12	$F(2, 322) = .45$, $p = .639$, $R^2 < .01$
Importance of Teacher Education in Digital Pedagogy (ITEDP)	M = 8.04 [7.81, 8.27]	$t(322) = 21.79$, $p < .001$, *Cohen's d* = 1.21	$F(2, 320) = 1.21$, $p = .300$, $R^2 < .01$
Extent to which schools should Rely on Online Learning (SROL)	M = 5.22 [4.96, 5.48]	$t(323) = -2.08$, $p = .038$, *Cohen's d* = .12	$F(2, 321) = .23$, $p = .798$, $R^2 < .01$
Degree of School's e-Maturity (SeM)	M = 6.36 [6.13, 6.59]	$t(324) = 7.33$, $p < .001$, *Cohen's d* = .41	$F(2, 322) = 1.98$, $p = .140$, $R^2 < .01$

Readiness of learning ecosystems. To investigate a) the capability of learning ecosystems to react to the epidemic and b) the details of the operational conditions that have been put in place, we employed univariate analyses. For Likert-type response scales, we carried out one-sample t-tests against the midpoint of the scale (5.5 for 10-point scales, *0 for the -5 to 5, 0 for the 0-100% scales*). The results are reported in Tables 1 and 2.

As shown in Table 1, we observed relatively high levels of perceived: a) readiness (SR) of schools to switch from f2f to online teaching (SP); b) technological adequacy of online environments used (TAOE); c) teachers' technological readiness (TTR); teachers' pedagogical readiness (TPR). Similar results have also been observed in [10] and partially in [14].

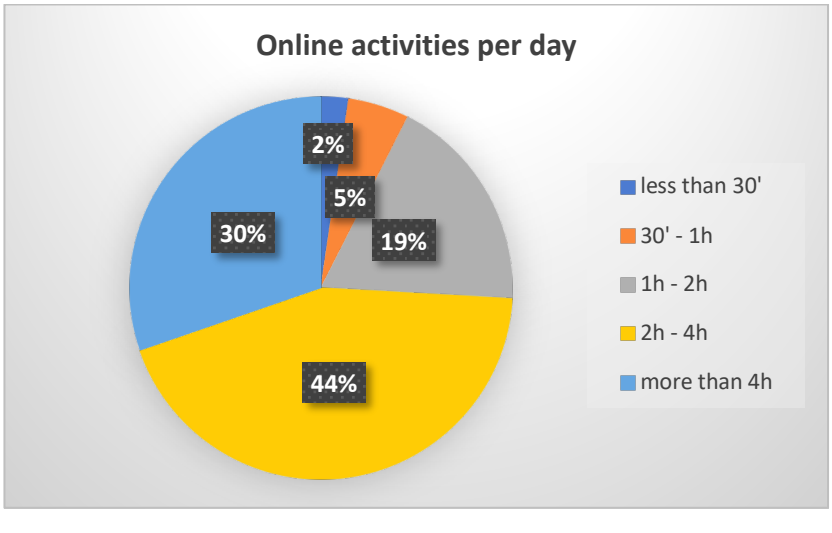


Fig. 2. Time teachers spent online per day to support and deliver distance learning

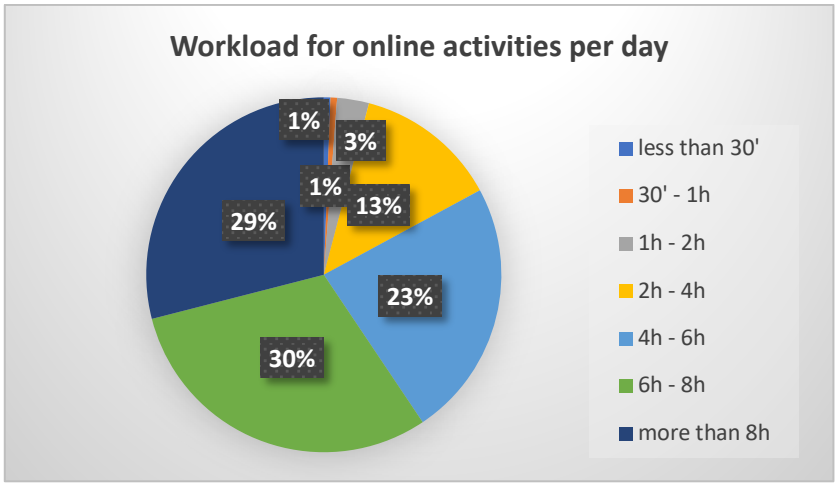


Fig. 3. Teachers' overall time-based workload per day to support and deliver distance learning

Workload and time organization. In spite of the abovementioned positive impressions, the shift to online education generated a substantial perceived increase in workload (estimated around 65% more than usual), as illustrated by figs. 2. and 3. The increased workload generated by online education during the pandemic is consistent with previous results [10, 14], although in [10] it seems more reduced than in Italy.

In the teachers' opinions, these operational conditions induced a lower self-reported capacity to manage their own time with respect to pre-COVID outbreak conditions: see (TTMC) in Table 1. The same effect holds true when teachers evaluate their students' time management capability: see (STMC) in Table 1. It is worth noting that in a case study conducted recently in two high schools located in Rome [13], the sample's opinion on (TTMC) proved to be more or less confirmed, while in contrast both students and parents thought that (STMC) improved.

Teaching activities. We asked teachers to rate the teaching activities they carried out during the lockdown along four axes: *lessons vs. discussions* (EALD in Table 1), *transmission vs. interaction* (EATI in Table 1), *asynchronous vs. synchronous* (EAAS in Table 1), and *individual vs. collaborative* (EAIC in Table 1) - all scales ranging from -5 to +5. As shown in Table 1, respondents deemed their lockdown-affected teaching activities to be more *discussion*-based (M = .37 [.13, .60], *interactive* (M = 1.06 [.81, 1.31]), *synchronous* (M = .85 [.58, 1.12]), and directed to *individuals* (M = -.36 [-.67, -.05]).

These results can easily be explained by the attempt to reproduce classroom dynamics. In fact, looking at fig. 4, one realizes that about 88% of the teachers delivered synchronous video-lectures, 82% assigned homework to be completed mainly individually, and 53% organized synchronous homework correction. Only 27% of teachers organized learning activities based on synchronous collaborative

work and less than 20% planned these for enactment in asynchronous mode, possibly because planning and implementing collaborative learning is deemed to increase workload. This is despite the considerable body of research findings supporting the multiple benefits of online collaborative learning based on asynchronous communication, and the many efforts devoted to training teachers in Italy to design and run activities of this kind [30]. It appears that due to the lack of time (or incentive), most teachers did not try, although a certain number did. More generally, only 12% attempted to organize activities of a more innovative nature; this may indicate either limited technological or pedagogical preparedness, or the reluctance (or inability) to dedicate the extra time and effort needed to design activities suitable for the new setting that go beyond traditional, often transmissive activities. Similarly, if we consider assessment modes (fig. 5), we can see that individual assignments, online tests, and synchronous oral interviews comprise the overwhelming majority of adopted methods. Collaborative and group assignments were used by less than 20% of respondents. Coherently, technologies (fig. 6) were largely employed to produce contents (76%) and share them (87%), assign homework (82%), deliver video lectures (56%), and organize synchronous classroom exercises (62%). The level of student-oriented personalization of teaching activities was fairly high (52%), –while employment of technologies as an opportunity to diversify teaching approaches – didactic and pedagogical side - was lower than one might expect (41%). Additionally, only one third of the teachers employed a digital environment to plan (39%) and manage (33%) educational processes, and this may indicate a tendency towards spontaneous/uncoordinated organization and delivery of learning activities. Another use of the technological environment that seems to have been rarely employed is for fostering socialization (19%). However, this outcome should not lead to the conclusion that socialisation between students did not take place altogether, as research evidence concerning social media use as a 'back-channel' alongside formal learning processes abounds in the literature, leading us to believe that social media might have served this purpose [28, 29].

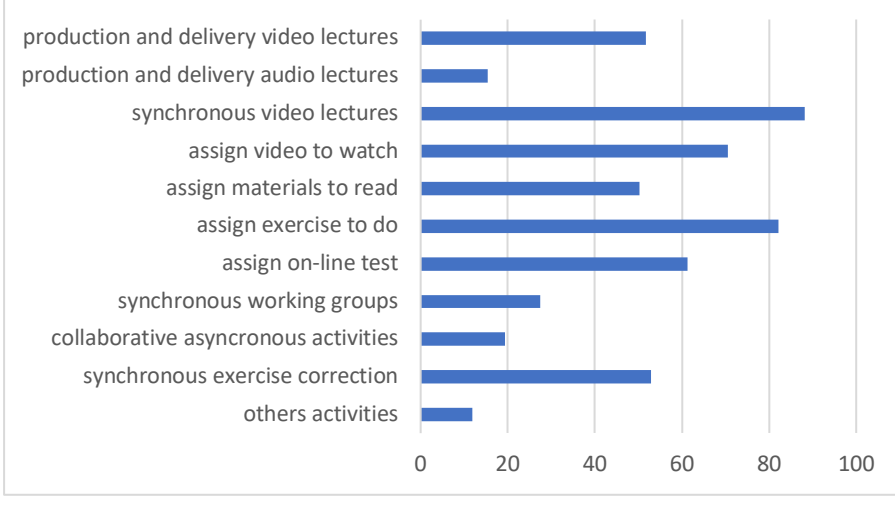


Fig. 4. Percentage of teachers who adopted the different types of learning activities listed

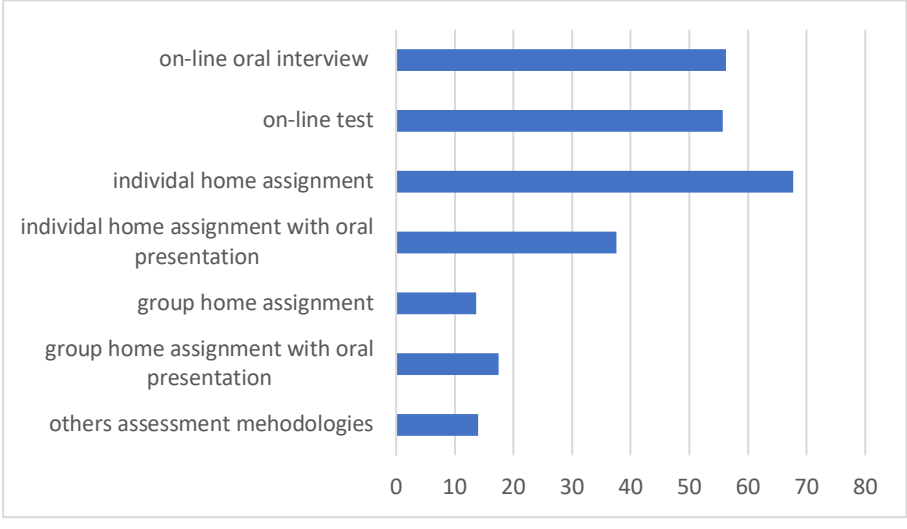


Fig. 5. Percentage of teachers who adopted the different types of assessment methodologies listed

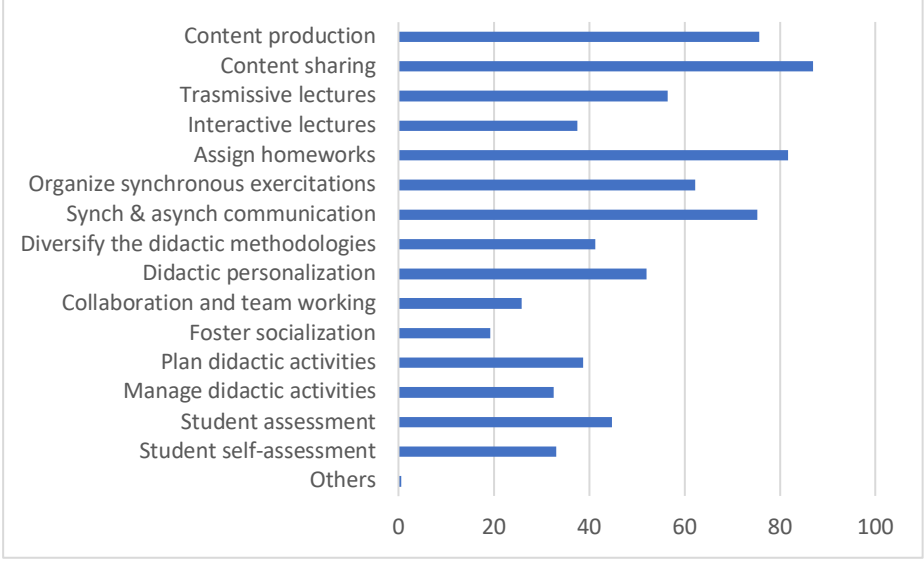


Fig. 6 Teachers' purposes for using technologies (%).

As for the difficulties teachers faced during their online experiences (fig. 7), the main one (reported by 40% of respondents) concerns the expressive modalities (D_SC), which are felt to be very limited with respect to f2f interaction (D_LE).

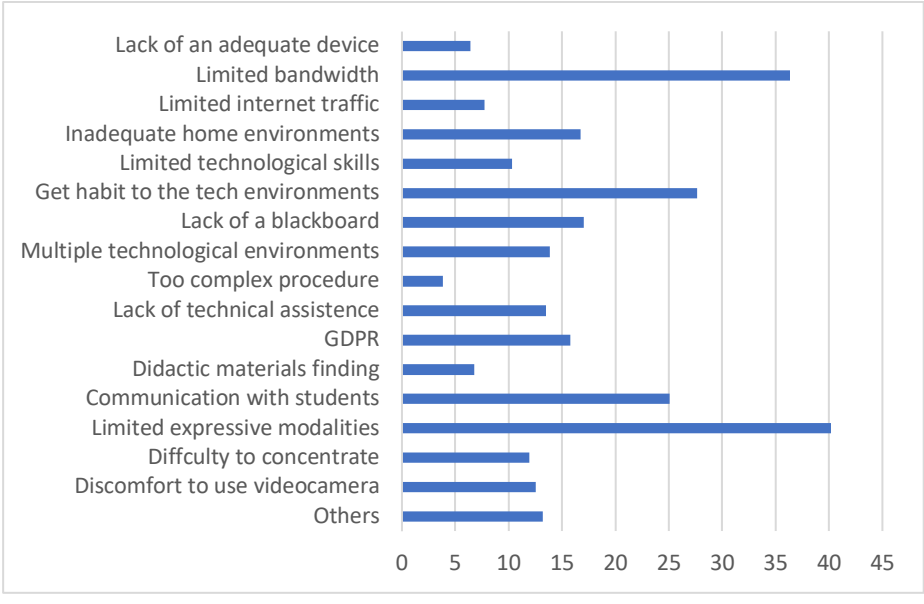


Fig. 7. Difficulties faced by teachers (%).

The second item in the ranking, as already mentioned above, is limited internet bandwidth, D_LC (36%). Apparently, the lack of technological skills is not felt to be a significant problem by 90% of the teachers, at least when implementing the educational strategies described in the previous section. However, 28% encountered difficulties accustoming themselves to novel technological environments, D_HT, while 14% reported difficulties using multiple environments (including tools and apps), D_MT, and lamented a lack of technical assistance. Similar percentages were found in [14]. It is interesting to note that in Italy 17% missed having a blackboard, D_MB.

Another notable aspect is the difficulty that 17% of the sample experienced due to unsuitable home environments, D_IHE, which may also have generated a perceived lack of concentration (12%), while 13% felt a certain discomfort in using a webcam. The percentage that experienced family problems (17%) turned out to be much lower than the 53% reported in [14]. Another interesting aspect is the relative lack of perceived problems associated to General Data Protection Regulation (GDPR), namely 16%. In normal conditions and in the case of strict compliance with GDPR provisions, the delivery of most of the activities carried out during the pandemic wouldn't be possible, especially in consideration of the fact that almost all the students involved were minors (in Italy, under 18 years old). This indicates that most of the sample considered restrictions related to GDPR are of little significance and can be freely bypassed, at least in emergency conditions. This finding differs sharply from the situation in [14], where 74% of the teachers expressed concern about privacy issues.

Looking to the future. Since at the time of the data collection the operational conditions could be considered as being "steady state", we also tried to stimulate initial reflection about possible future developments. Interestingly, we observed (Table 2) a significant improvement in attitudes towards digital technologies (IAT), which may be related to improvement in technological skills (ITS) and general agreement on the need to train present and future teachers in digital pedagogy (ITEDP). Similar positions are also evident in [10 and 14]. On the other hand, we also observed a diversity of opinions on the intention to continue working with online learning (IWOL), on how much the school should rely on online learning activities (SROL), on the change in their idea of educational experience (CIEE) and, overall, on the perceived sustainability of the online learning (SOE). The discrepancy in teachers' opinions is evident in the wide range and high dispersion of responses to these variables.

Despite this contrast in opinions, all in all, the online teaching experiences made necessary by the pandemic outbreak seems to have induced a quite positive opinion on the e-maturity of schools (SeM in Table 2). This is a complex construct comprising not only the quality and adequacy of technological settings and available digital competencies but also other variables, including effectiveness in the management of digital environments and of the learning processes and the vision of the development of the digital setting [26].

Finally, the preferred future teaching mode is largely f2f (66%) but a considerable number of teachers (32%) would prefer, and feel ready, to continue in blended configuration. This latter percentage is quite high compared with what we would have expected during the pre-COVID time. Although we cannot make a direct comparison with pre-emergency data, in 2019 the number of Italian teachers registered in the eTwinning community was 70,000 [25], i.e. less than 10% of all Italian teachers; this figure corresponds more or less to the percentage of those who are commonly considered innovative teachers [24]). As expected, compared with the average reported in fig. 8, the preference for blended configuration is lower among primary than secondary school teachers.

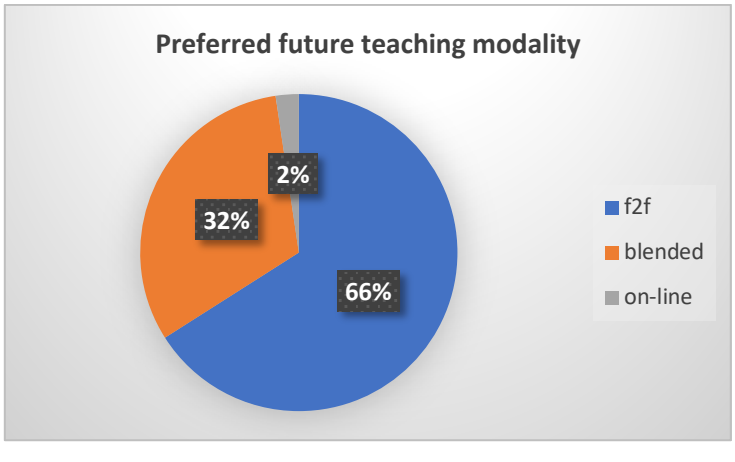


Fig. 8. The teachers' preferred future teaching modality.

The scenario and data described above, however, do not allow us to clearly identify the relationships among the investigated variables (Tables 1 and 2), nor their possible causal dependences. In the next sections we will try to shed light on this aspect and complete the answer to our research question.

3.2. Prediction, correlation and causality

Linear regression models. Our exploration of variable associations started with standard linear regression models, with the objective of identifying the variables that would most accurately predict what we consider to be key outcomes. The variables we sought to predict are the intention to engage in online education in the future (IWOL), the belief that technology-based education is sustainable (SOE), and change in the idea of educational experience (CIEE). The main predictors tentatively considered were age, location (North / Centre / South Italy), school level, perceived school technological readiness, the eight most commonly reported difficulties (i.e. difficulty in adapting to new tools and environments; having to use too many new tools; working in an unsuitable environment; having limited connectivity/bandwidth; limited expression modalities; difficulty in communicating; missing a blackboard; and difficulties with GDPR), the four axes of proposed activities, self-reported change in time management capacity, and estimated change in time management capacity among students.

Regarding the intention to engage in distance education in the future (Adjusted R^2 = .25), the main predictors seem to be change in time management capacity, TTMC (b = .20, $t(299)$ = 3.74, p < .001) and change in students' time management capacity, STMC (b = .24, $t(299)$ = 3.82, p < .001), followed by perceived school technological readiness, TAOE (b = .22, $t(299)$ = 3.34, p < .001), difficulty in getting used to new tools and environments (b = -.90, $t(299)$ = -2.49, p = .013), and teaching at upper secondary level (b = -.89, $t(299)$ = -2.47, p = .014).

Regarding the perceived sustainability of technology-based education (Adjusted R^2 = .23), this mainly seems to be predicted by self-reported change in time management capacity (b = .13, $t(304)$ = 3.11, p = .002), students' change in time management capacity (b = .19, $t(304)$ = 3.83, p < .001), perceived school technological readiness (b = .21, $t(304)$ = 4.10, p < .001), difficulty in getting used to new tools and environments D_HT (b = -.57, $t(304)$ = -2.00, p = .046), and reporting unsuitable home working environment, D_IHE (b = -.74, $t(304)$ = -2.22, p = .027).

Lastly, change in respondents' idea of educational experience (CIEE) pedagogical ideas (Adjusted R^2 = .10) is only predicted by self-reported change in time management capacity (b = .12, $t(296)$ = 2.30, p = .022), change in students' time management capacity (b = .13, $t(296)$ = 2.05, p = .042), and teacher age (b = -.04, $t(296)$ = -2.43, p = .016).

Partialized correlations. While multiple linear regression can help us understand which variables seem to be the best predictors of specific outcomes, the complexity of the topic being examined warrants a more comprehensive approach, since many of

the variables under consideration are strongly associated and may interact in complex ways.

Network analysis offers useful tools for visualizing complex webs of variable relationships; these include the plotting of least absolute shrinkage and selection operator (LASSO) regularized partial correlation networks [31].

Partial correlations measure the degree of association between two variables after controlling for all other variables being considered; as such, they are a useful measure of direct association. Using partial correlations instead of the more common 0-order correlations [32] helps rule out spurious correlations that ostensibly appear to be meaningful while examining 0-order correlation matrices.

Using LASSO regularization further aids in the interpretability of the network by only visualizing relatively strong associations and setting to 0 all weaker associations. This simplification reduces statistical background noise, guiding the interpretation of results towards more meaningful associations. In fig. 9, we report the LASSO-regularized partialized network of the main variables considered in the study (tuning parameter for the LASSO was set at 0.5).

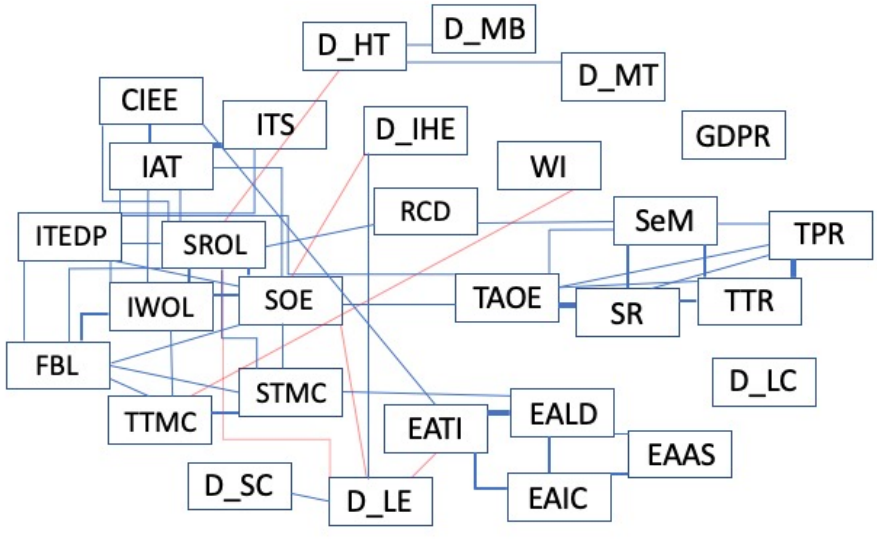


Fig. 9. LASSO-regularized partialized network of the main variables considered in this study

In the graph, wider lines represent stronger associations. Positive partialized correlations are shown in blue, while negative partialized correlations are in red. Visual examination of the graph shows that, for example, activity axes form an almost isolated cluster: they are related to each other, but are very weakly related to few other variables. Among difficulties, the only one that seems to have strong associations with other variables is unsuitable home environment (D_IHE), which seems to (slightly) reduce perceived sustainability of online learning (SOE, .08) and increase the tendency to reproduce classroom dynamics (RDC, .07). Readiness of schools (SR) and teachers (TTR and TPR), as well as e-maturity (SeM), form a strong correlated cluster but seem to be related also to the perceived adequacy of the school's digital

technology provision (TAOE), which, in turn, is related to perceived sustainability of online learning (SOE, .31).

In accordance with regression models, time management capacity – of both teachers (TTMC) and students (STMC) – seems to be related to beliefs about the future employment of online learning (SROL; .27 and .36, respectively). However, after accounting for all other variables in the dataset, their relation to future intentions (IWOL; both .31) and perceived sustainability (SOE; .28 and .33, respectively) appear to be weaker than what was suggested by multiple linear regression. Instead, the main variables associated with outcome variables are previously-held beliefs about the Importance of Teacher Education in Digital Pedagogy (ITEDP) and more positive attitude towards educational technologies (IAT). It is important to note that these apparent inconsistencies between linear regression are, to an extent, to be expected: network analysis considers all variables at once, resulting in fewer spurious links with outcome variables thanks to taking into account correlations and mediations involving linear regression predictors. In addition, LASSO regularization favours sparse, parsimonious networks by culling weaker effects from the graph. Therefore, while linear regression offers a useful approximation of which variables predict specific outcome variables, network analysis results should be considered as providing a more comprehensive picture.

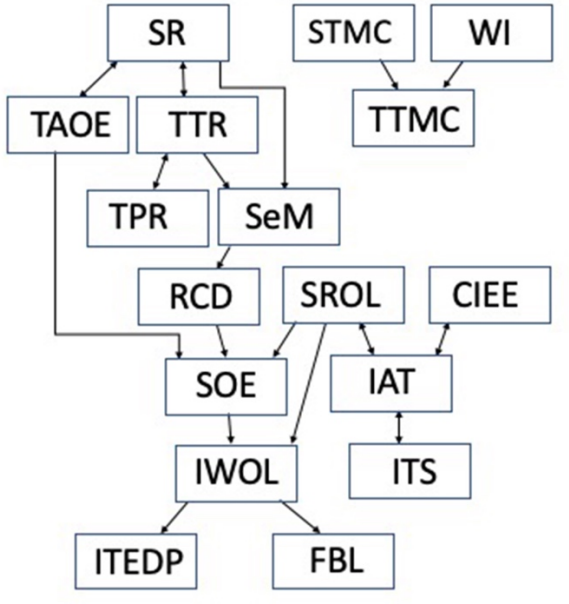
The relationships demonstrated by fig. 9 will be further examined in the next subsection.

Causal discovery. One of the main drawcards of network analysis is the possibility to infer causal relationships from observational data. This is based on Pearl's concept of d-separation [33], by which we mean a set of criteria that can determine whether two (sets of) variables are independent, given a set of other variables. The key part of the procedure is finding, in the graph, three variables – X, Y, and Z – such that: (1) Y is connected to both X and Z; (2) X is not connected to Z (when considering 0-order correlations); and (3) X and Z are *not* independent when conditioning for Y. If such a set of variables exists, it is possible to orient towards Y both the edge connecting Y and X and the edge connecting Y and Z. This is because X and Z would be independent (when conditioning on Y) only if they are common causes of Y. Were there to be a chain (either X -> Y -> Z or X <- Y <- Z), X would be independent from Z when conditioning on Y; and the same holds true for the only other possible configuration, namely X <- Y -> Z. Directing those edges puts new constraints in place, which can be used to further infer the direction of edges in the graph.

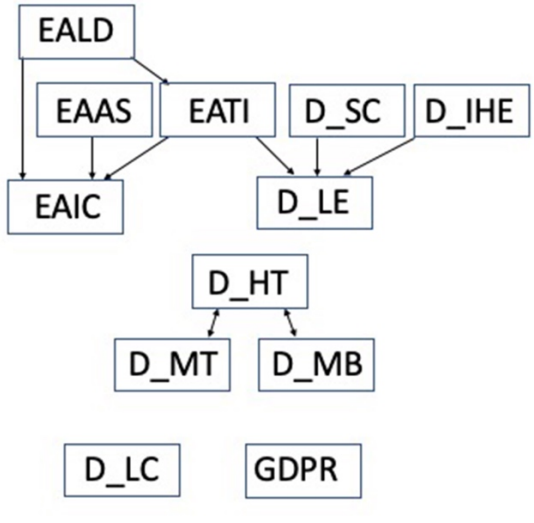
A simple implementation of this iterative procedure is the PC algorithm, which identifies the causal structure reported in fig. 10 (using $\alpha = .01$ and an order-independent and non-conservative version of the algorithm (see [34] for details).

It should be noted that a major drawback of this procedure is that it relies on strict assumptions, which are rarely met in real-world data. For example, accurate causal discovery would require that there are no hidden variables (and especially hidden common causes) in the network. As such, results from the PC algorithm should be interpreted tentatively, and not regarded as factual results. However, in a purely exploratory analysis such as this one, they can aid and guide interpretation of results.

From fig. 10 we can observe that some variables are, indeed, where we would expect them. For example, the intention to engage in online education (IWOL) or the preference for blended learning in the future (FBL) are both at the end of the causal chain, like the Importance of Teacher Education in Digital Pedagogy (ITEDP).



a)



b)

Fig. 10. Causal structure of the main variables considered in this study.

This aligns with our theoretical understanding, for which intention to use is a *result* of several processes and conditions, rather than a cause. Schools' (perceived) readiness (SR) and adequacy of technology (TAOE), on the other hand, are towards the start of the causal structure, and they are indeed preconditions that are unlikely to be effects, for example, of the capacity of teachers to reproduce class dynamics (RCD).

The e-maturity of schools (SeM) seems to be the only variable to have a direct effect on the capacity of teachers to reproduce classroom dynamics (RCD); this, in turn, appears to have a cascading effect on the perceived sustainability (SOE) of online education and the intention to employ online education in the future (IWOL). This can be understood in the following way: e-maturity has been interpreted, instead, as a global indicator [26] that supports the smartness of the learning ecosystem [35], as a complex variable which includes both perceived school and teacher readiness, and thus is used as a predictor of teachers' expectations during this emergency period: reproducibility of the classroom dynamics.

It is interesting to note how a more positive attitude towards digital technologies (IAT) is related with the perception of an increase in digital/technical skills (ITS), with changed idea of educational experience (CIEE) and with the belief that in future the school should rely, at least partially, on online learning (SROL). An unexpected finding is the causal relation between SROL and SOE. One would have expected an influence of the perceived sustainability of online learning (SOE) on school reliance on it (SROL), and not the contrary. This apparent anomaly could be explained by a possible preconception: I believe that the school should use online learning, at least partially, and therefore this approach becomes sustainable. Another interesting insight is how teachers' time management capacity seems to be influenced by the (perceived) time management capacity of students. Poor time management on the part of students may well disrupt the schedule of teachers.

The graph in Fig. 11b offers some insights into potential relationships between variables. For example, experiencing difficulty due to the limited capacity of expression (D_LE) during online education seems to actually be an effect of difficulty in communicating with students (D_SC) and having an unsuitable home environment (D_IHE). As such, we could predict that making teachers' home environment more suitable for working would have a positive effect on their expressivity using online education tools, even if the tools themselves are unchanged. As might be expected, D_LE seems to be caused by the prevalent interactive characteristic of the learning activities (EATI). EATI, together with the prevalent synchronous nature (EAAS) and prevalence of discussion (EALD), contribute to the delivery of learning activities intended more for individual use rather than for collaborative work.

4. Conclusions and future work

The present paper provides a snapshot of the learning ecosystems' - Institutions and teachers - reaction to the Covid-19 pandemic as well as the online educational processes delivered under steady state operational conditions, as seen from the teachers' perspective. It also explores the directed network of relationships among the

set of variables that we have considered in this survey. This sheds light on how contextual variables and operational conditions can modify teachers' mindset and expectations about technologies and online learning. Importantly, it also establishes a benchmark for future surveys and research aimed at investigating similar phenomena in the same or similar contexts and, more in general, for future studies on the adoption of online learning. Due to the need to provide timely data, the literature available when the paper was written is limited. However, the theme is being investigated by several research groups and a summary of the first published results is provided by Giovannella et al [41].

This study demonstrates the reasonable e-maturity and robustness of both the Italian school system and its technological infrastructure, which did not collapse thanks to the promptness and professionalism of teachers capable of overcoming a multitude of personal difficulties (increased workload, poor internet connectivity, the unsuitability -in some cases - of the home setting as a workplace, etc.) to ensure educational continuity. It should be noted, though, that the widely adopted technological infrastructures featured freely available, easy-to-use cloud-based video conferencing applications, as well as of user-friendly modular collaborative cloud-based working environments. Fashioned for e-learning purposes (e.g. Google Classroom), these ensured, at the very least, content sharing and co-production, and basic assessment procedures (see figs 4-6).

All of this would not have been possible just a few years ago [11, 12]. Nevertheless, teachers also reported a potential risk of digital divide for 6%-10% of the student population, an issue that deserves special attention and suitable counteractions in terms of both policy making [9] and research on inclusive education. The teaching strategies adopted by most teachers in this emergency are, in fact, very far from ideal solutions for maximising inclusiveness. For example, a more intensive use of asynchronous communication tools would probably have attenuated the exclusion effects pointed out by our data [36].

Technology adequacy and teachers' readiness are two main components of the e-maturity of a digital learning ecosystem, whose value influences the perception of sustainability of online learning and the intention, in a third of the teachers, to use it in the future (blended configuration). It should be noted, though, that these factors are related to the self-reported "capacity to reproduce classroom dynamics" and, more in general, to a feeling of "comfort": comfort in the use of technologies at an individual level generating a feeling of *empowerment* and increased digital competence; comfort at institutional level from the prompt school responses and the adequacy of technologies made available; comfort because all this has led to reproduction of the educational dynamics to which teachers are generally accustomed. As we know, the acceptance of technologies, and in this case of a change in teaching methods (based on a more or less broad spectrum of technologies), is often reliant on the perception of simplicity and usefulness, factors which, in our case, are multifactorial. In addition, the successful integration of online activities also depends on teacher training that favours the lowering of related mental and cultural barriers Only at a later time will it be possible to induce the desire to go further and experiment with more advanced technology-augmented approaches, ones that could disrupt, rather than reproduce, traditional transmissive pedagogical approaches.

In other words, during the pandemic, teachers had a tendency to use technologies to reproduce traditional transmissive teaching dynamics, which is a reductionist approach to Technology Enhanced Learning [37]. However, at the same time, a high degree of comfort in the learning ecosystem could, in the future, lead them to depart from such dynamics and enact more creative learning experiences.

Maybe, beside concern about the provision of personal protection equipment, we should finally start dedicating more effort towards the realization of modular learning environments that are interoperable, sustainable, cloud based, open, easy to access and use, capable of satisfying basic educational needs and of being used as a driver for the gradual introduction of more pedagogically advanced practices (a large proportion of learning processes conducted f2f, blended, or on-line, are, in fact, still transmissive ones).

The present work should be considered as a starting point for further analysis, research and surveys that could be oriented in several different directions. The time constraints imposed on this study required us to use a bespoke questionnaire, which did not undergo a proper validation process. As a first step, the results should be confirmed using a more robust framework. Additionally, we intend to analyse in greater depth the textual answers and comments participants provided in the present survey in order to confirm the scenario that has emerges from the quantitative analysis performed. This would shed light on the relevant details and possible contradictions that may be hidden behind that scenario, and/or highlight potential differences in attitude among different teacher categories. Other interesting directions that will be explored in the short-term period concern comparison between the perspective of Italy's school teachers and that of university teachers (primary and secondary education vs tertiary education) and between school teachers and students' parents (schools vs. families). Comparing the perspectives of all the main actors in a learning ecosystem, on the other hand, is to be carried out via local case studies, since these allow comparison between individuals that belong for sure to the same context. As for the specific investigations reported in this paper, all future analysis will be conducted with two overarching aims in mind: 1) to capture an instant picture of the extraordinary occurrence represented by educational processes enacted during a pandemic; and 2) deriving lessons to be learnt both for the future of the technology enhanced learning and its integration in the educational processes and for the further development of digital pedagogy and digital education literacy. These latter aims go hand in hand with further appropriate development of and access to infrastructure in order to guarantee everyone in all countries has individual, high quality access to the internet. Future high-quality education for all (see Sustainable Development Goals 4 [38]) needs to consider the digital dimension, the avoidance of digital divide, and the sustainability of the digital infrastructures, all aspects that have not been sufficiently emphasised in the description of the UN 2030 Sustainable Development Goals. Consequently, in the medium-long term, it would also be very important to promote comparative studies on the data being collected all over the world while we write. Finally, we deem it very important to perform follow up investigation of evolution in the perception of participants in this and other surveys, and of the settings in which they operate, so as to shed light on any persistent effects that may have been induced by the pandemic, irrespective of political measures introduced in the meantime and of impact from social pressure.

Further research could also investigate the impact on teacher competence and school digital readiness brought about by substantial resource investment made at regional, national and European levels aimed at developing those competences and making available tools for technology-enhanced learning. In terms of digital competences, our respondents reported being - on average - better off than expected by many [16, 20, 3], although our data do not allow us to ascribe the merit to specific national or international initiatives. In terms of infrastructures, the cloud applications most widely adopted during the emergency were commercial ones, even if early exploration of the educational value of the functionalities they offer may be traced to the EC VII Framework Program. It would thus be interesting to look for correlations between teachers' competence and digital skills and their previous involvement in research initiatives concerning Technology Enhanced Learning, or exposure to related research results.

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