A comparative study on the effects of the COVID-19 pandemic on three different national university learning ecosystems as bases to derive a Model for the Attitude to get Engaged in Technological Innovation (MAETI).

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Abstract. This paper reports the outcomes of a unique investigation coordinated by ASLERD that had the aim of comparing the effects of the COVID-19 pandemic on three learning ecosystems with different cultural backgrounds and settings: Iraq, Italy and Mexico. Using the same questionnaire translated from Italian to English, Arabic and Spanish, the study has investigated these ecosystems through the lens of University teachers. Despite cultural and infrastructural differences that unavoidably influenced the outcomes, we have detected common effects in the three samples, such as an increase of the working load and a better organization of the time at individual level. Network analysis methods also allowed us to identify some relationships between variables common to the three contexts. In particular, some variables clustered in all samples: a cluster related to the setting (infrastructure and technologies, competences and readiness to respond), one related to the characteristics of the didactic activities, and one related to expectations for the future about use of and involvement in on-line learning. In addition, the reproducibility of classroom dynamics seems to have high betweenness centrality in all three networks. In one case, that of Iraq, we have been also able to include in the causal networks the factors considered by the TAM (Technology Acceptance Model), but the networks appear not to be substantially influenced by the inclusion of TAM variables. On the basis of these results, we propose a Model for the Attitude to get Engaged in Technological Innovation (MAETI), to be used as possible reference framework for future investigation on the effects induced by technologies on use intentions.

Keywords: COVID-19 pandemic, on-line learning, learning ecosystems' reaction, Italy, Mexico, Iraq, university teachers, future perspectives, descriptive analysis, causal discovery, MAETI.

1 Introduction

As well – and sadly – known, in the first half of 2020 almost all educational ecosystems (schools, universities, private centers, etc.) around the globe were forced to cancel face-to-face (f2f) classes as a non-pharmaceutical intervention to contain the spread of COVID-19 pandemic [1]. While we are still learning from the data collected during the first lockdown [2], a large part of the countries have reopened schools and universities as an "not-monetary intervention to contain the spread of the economic crisis", putting in the background any didactic and pedagogical consideration on technology-supported educational processes. The main efforts during the last few months have been concentrated on making the physical spaces of learning ecosystems safer and on the design of emergency plans to manage possible future temporary switches to on-line learning in case of new pandemic waves. Luckily, the latter measures have included at least a partial retraining of teachers. At present, negative considerations about on-line teaching – as compared to face-to-face teaching – seem to prevail, but the main arguments make reference to psychological and social issues. These considerations slowed down and reduced the efforts dedicated to the analysis of the reaction of the ecosystems to the pandemic and in particular of the individuals: a) to react to a sudden introduction of technologies that impacted on the routines of learning processes; b) to foresee, possibly, technological integration in future learning processes.

Despite the present position of most of the world governments, it is still very important from a cultural point of view to investigate in detail the reaction of the learning ecosystems, which may depend on the cultural and infrastructural setting. With this respect, the present work, coordinated by the ASLERD (Association for Smart Learning Ecosystems and Regional Development) [16], attempts for the first time a comparative analysis of three different university ecosystems – the Iraqi, the Italian and Mexican ones – using the same questionnaire [3] translated from Italian into Arabic, English, and Spanish.

The results, as shown in the following sections, highlighted differences among the learning ecosystems but also important similarities in the relationships between the variables investigated. This, as shown in the last section, led us to draft a tentative model for the interpretation of the reaction of individuals to a sudden technological-based transformation that may affect learning ecosystems (and other ecosystems) and the educational processes (working processes) that are delivered. Hopefully, this investigation and future ones will shed light on the mechanisms that may favor a transformation and modernization of the learning processes guided by a pedagogically based integration of digital technologies.

2 Method

2.1 Questionnaires

The surveys were carried out by means of a three-section questionnaire comprising 81 items in the case of Italy and 84 items in the case of Iraq and Mexico. The survey was similar to the one used in [4], but readapted to the university context. The first section comprises six socio-biographical background items (gender, age, university sector, teaching area, geographical location and university name). The second section presents 36 items (21 questions requiring a multiple choice or numerical answer and 15 open questions or requests for explanatory comments) for the Italian case and 38 items in the case of the Iraqi and Mexican cases (23 questions requiring a multiple choice or numerical answer and 15 open questions or requests for explanatory comments). Section two investigates respondents' perceptions about how the learning ecosystem responded to the pandemic. In the case of Iraqi and Mexican surveys, that have been distributed a few months after the Italian one, we have introduced two additional questions to verify relevance and position of the perceived *easiness to use* and *usefulness* of on-line learning, the two main variables used in the traditional TAM (Technology Acceptance Model) [5-6]. The third section comprises 39 items (19 questions requiring a multiple choice or numerical answer and 20 open questions or requests for explanatory comments) for the Italian case and 40 items for Iraqi and Mexican cases. This latter section investigates any changes in university teachers' opinions about technologies and online learning and expectations for the future. The complete English questionnaire is available at [7].

It is important to stress that in Italy the survey has been distributed [3] about two months into the universities' lockdown (which started on March 5th, 2020), during the delivery of the educational process at what we may consider "steady state" operating conditions. The survey was active for one month, from May 1st, 2020 to June 1st, 2020. In Mexico, data were collected during the month of September, i.e. the second half of the scholar year, immediately after the summer vacation; at that time it was not clear if the shutdown would continue until the end of the year. In Iraq, the collection of data started about 5 months after the lockdown start (February 27th, 2020) and just before the final exam of the second semester. The survey was open for approximately three weeks and started on July 25th, 2020.

In the following, we report the outcomes of the analysis of multiple choices and quantitative answers, with the aim of providing a comparative snapshot of the situation in the three different Countries and investigating university 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 variables might have influenced teachers' perception of technology and their expectations for the future (see Table 2). We will firstly present the outcomes of a descriptive analysis and, secondly, a detailed comparative study of the networks of variables' relationships as obtained via a widely-used causal discovery process. To conclude, we will present an attempt to draft a Model for the Attitude to get Engaged in Technological Innovation (MAETI) that in future could be used as reference framework for future investigation on the effects induced by technologies on use intentions.

2.2 Participants

In Italy, participants were contacted directly via emails and mailing lists. The questionnaire was filled in by 546 University teachers (263 women, 280 men, 3 non-binary) employed mainly in public universities (98%). The mean age of the respondents, 52.4 years, aligns perfectly with that of the national population of the university teachers [8]). Participants reported teaching in 16 different scientific and humanistic cultural areas, with a prevalence of STEM (Science, Technology, Engineering and Mathematics) (33.9%) and Medicine and Surgery (19.2%). Participants are employed in more than 25 Universities located all over Italy.

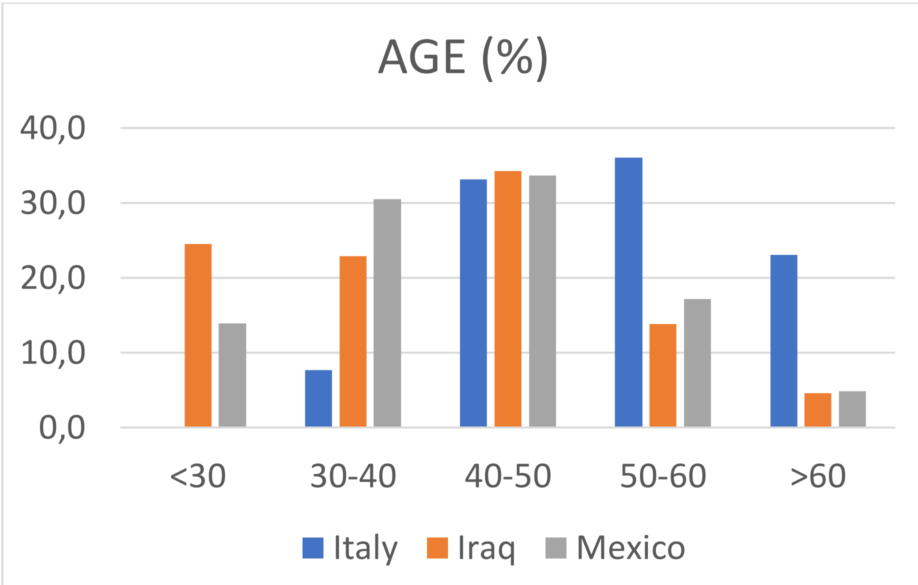

Fig. 1: Faculties' age distribution (%). Estimated average age (years): Italy = 52.4; Iraq = 40.1; Mexico = 41.8

In Iraq, participants were recruited via different channels such as social media and emails. The survey was filled in by 572 university teachers (237 women, 330 men, 5 non-binary) employed mainly in public universities (99.3%). The mean age of respondents was 40 years. Participants reported teaching in 16 different scientific and humanistic cultural areas including humanities (19.2%), Mathematical, Physical, Chemical and Natural Sciences (12.9%), educational Sciences (9.8%). Respondents were employed in more than 35 universities and colleges located all over Iraq.

In Mexico, the questionnaire was disseminated through social networks and e-mails. It was filled in by 187 university teachers, 78 women, 107 men and 2 non-binary; the estimated average age of the respondents is 41.8 years. Although a smaller sample than the Italian and Iraqi ones, the sample seems to be representative of Mexican University teachers in term of gender distribution and age [9]. Most of the respondents work in public universities (88%), while according to the SEP (Secretariat of Public Education) the percentage of teachers in the superior education in the face-to-face modality (undergraduate and postgraduate studies) working in public organization represents the 59.5% of the population [10].

We can notice that the mean age of the respondents in Italy is higher than in the other learning ecosystems, while gender distribution appears to be more balanced.

The fatiguing effect that may have been induced by the length of the questionnaire turned out to be very low in Italy, with less than 5% of multiple choice and numerical-answer questions being skipped, even towards the end of the survey. Drop-out rate was even lower in Mexico, about 2%, but doubled in Iraq, about 12%.

In this paper, we restrict our analysis to the answers given to multiple choice and numerical-answer questions.

3 Results

To explore university 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, as in [3-4].

First, to investigate a) the perceived capability of learning ecosystems to react to the epidemic, and b) the details of the operational conditions that have been put in place, we carried out descriptive and univariate analyses (section 3.1). 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 scales ranging from -5 to 5, 0 for the 0-100% scales). The results of the t-tests have been reported in Tables 1-4 for the Iraqi and Mexican cases, while those concerning the Italian case have been already reported in ref [3].

Subsequently, to obtain a bird's-eye view of the variables' relationships, we employed network analysis to obtain a graph of variables' associations. More specifically, we used the PC algorithm to infer the direction of causality in the graph to aid interpretation (section 3.2).

Table 1. Iraqi survey Section II: teachers' perception about the capability of the learning ecosystems to react, the operational conditions and the features of the educational activities carried out.

Variable	**Average**	**t-test**
University Readiness to swap to on-line education (UR)	M = 6.95 [6.74, 7.15]	$t(573) = 14.06, p < .001$, *Cohen's d* = .59
Technological Adequacy of On-line Environments (TAOE)	M = 5.91 [5.70, 6.12],	$t(565) = 3.85, p < .001$, *Cohen's d* = .16
Previous Experience in On-line Learning (PEOL)	M = 4.55 [4.32, 4.78]	$t(560) = -8.11, p < .001$, *Cohen's d* = -.34
Teachers' Technological Readiness (TTR)	M = 5.84 [5.65, 6.03]	$t(570) = 3.51, p < .001$, *Cohen's d* = .15
Teachers' Pedagogical Readiness (TPR)	M = 5.79 [5.59, 5.98]	$t(570) = 2.88, p = .004$, *Cohen's d* = .12
Workload Increase (WI) %, tested against the baseline of 0	M = .57 [.55, .59]	$t(569) = 48.98, p < .001$, *Cohen's d* = 2,05
Teachers' Time Management Capacity (TTMC) (scale -5, +5)	M = 1.48 [1.25, 1.71]	$t(569) = 12.60, p < .001$, *Cohen's d* = .53
Educational Activity: Lecture-Discussion (EALD) (scale -5, +5)	M = .94 [0.69, 1.18]	$t(545) = 7.51, p < .001$, *Cohen's d* = .32
Educational Activity: Transmissive-Interactive (EATI) (scale -5, +5)	M = 1.40 [1.16, 1.65]	$t(541) = 11.16, p < .001$, *Cohen's d* = .48

Educational Activity: Asynchronous-Synchronous (EAAS) (scale -5, +5)	M = 1.06 [0.81, 1.30]	*t(539)* = 8.50, *p* < .001, *Cohen's d* = .37
Educational Activity: Individual-Collaborative (EAIC) (scale -5, +5)	M = 1.33 [1.08, 1.57]	*t(542)* = 10.76, *p* < .001, *Cohen's d* = .46
Reproducibility of Classroom Dynamics (RCD)	M = 6.08 [5.91, 6.24]	*t*(558) = 6.77, *p* < .001, *Cohen's d* = .29
Easiness to use On-line Learning (EUOL)	M = 6.47 [6,27, 6.67]	*t*(524) = 9.67, *p* < .001, *Cohen's d* = .42
Usefulness of On-line Learning (UOL)	M = 6.35 [6,13, 6.57]	*t*(522) = 7.73, *p* < .001, *Cohen's d* = .34

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

Variable	Average	t-test
Sustainability of On-line Education (SOE)	M = 5.87 [5.66, 6.08]	*t*(546) = 3.39, *p* < .001, *Cohen's d* = .15
Change in the Idea of Educational Experience (CIEE)	M = 6.28 [6.06, 6.49]	*t*(529) = 7.14, *p* < .001, *Cohen's d* = .31
Improvement in the Attitude towards Technologies (IAT)	M = 7.05 [6.84, 7.26]	*t*(531) = 14.66, *p* < .001, *Cohen's d* = .64
Improvement in Technological Skills (ITS)	M = 7.04 [6.85, 7.23]	*t*(528) = 16.00, *p* < .001, *Cohen's d* = .70
Intention to Work in On-line Learning (IWOL)	M = 6.33 [6.12, 6.54]	*t*(522) = 7.74, *p* < .001, *Cohen's d* = .39
Importance of Teacher Education in Digital Pedagogy (ITEDP)	M = 6.62 [6.41, 6.83]	*t*(516) = 10.41, *p* < .001, *Cohen's d* = .46
Extent to which University should Rely on On-line Learning (UROL)	M = 6.51 [6.30, 6.73]	*t(519)* = 9.25, *p* < .001, *Cohen's d* = .41
Degree of University e-Maturity (UeM)	M = 5.71 [5.52, 5.91]	*t*(519) = 2.14, *p* = .033, *Cohen's d* = .09

Table 3. Mexican survey Section II: teachers' perception about the capability of the learning ecosystems to react, the operational conditions and the features of the educational activities carried out.

Variable	Average	t-test
University Readiness to swap to on-line education (UR)	M = 6.14 [5.82, 6.47]	*t*(185) = 3.96, *p* < .001, *Cohen's d* = .29
Technological Adequacy of On-line Environments (TAOE)	M = 7.21 [6.89, 7.53],	*t*(184) = 10.64, *p* < .001, *Cohen's d* = .78
Previous Experience in On-line Learning (PEOL)	M = 6.36 [6.02, 6.70]	*t*(184) = 4.97, *p* < .001, *Cohen's d* = .37
Teachers' Technological Readiness (TTR)	M = 5.41 [5.09, 5.72]	*t*(184) = -0.59, *p* = .553, *Cohen's d* = -.04
Teachers' Pedagogical Readiness (TPR)	M = 5.48 [5.18, 5.77]	*t*(184) = -0.16, *p* = .872, *Cohen's d* = . -0.01
Workload Increase (WI) %, tested against the baseline of 0	M = .58 [.54, .62]	*t*(185) = 27.90, *p* < .001, *Cohen's d* = 2,40
Teachers' Time Management Capacity (TTMC) (scale -5, +5)	M = .54 [.15, .92]	*t(185)* = 2.74, *p* = .006, *Cohen's d* = .54
Educational Activity: Lecture-Discussion (EALD) (scale -5, +5)	M = -0.63 [-0.99, -0.26]	*t(184)* = -3.39, *p* < .001, *Cohen's d* = -.24
Educational Activity: Transmissive-Interactive (EATI)	M = 0.55 [0.21, 0.91]	*t(185)* = 3.13, *p* = .002, *Cohen's d* = .23

(scale -5, +5)		
Educational Activity: Asynchronous-Synchronous (EAAS) (scale -5, +5)	M = 0.21 [-0.16, 0.57]	*t(184)* = 1.11, *p* = .269, *Cohen's d* = .08
Educational Activity: Individual-Collaborative (EAIC) (scale -5, +5)	M = -0.57 [-0.97, -0.17]	*t(185)* = -2.84, *p* = .005, *Cohen's d* = -.21
Reproducibility of Classroom Dynamics (RCD)	M = 5.58 [5.25, 5.90]	*t*(185) = 6.77, *p* = .650, *Cohen's d* = .03
Easyness to use On-line Learning (EUOL)	M = 6.59 [6,29, 6.90]	*t*(184) = 7.13, *p* < .001, *Cohen's d* = .52
Usefulness of On-line Learning (UOL)	M = 7.77 [7,51, 8.03]	*t*(184) = 7.73, *p* < .001, *Cohen's d* = 1.27

Table 4. Mexican Survey Section III: teachers' perception about technologies and their expectations for the future

Variable	**Average**	**t-test**
Sustainability of On-line Education (SOE)	M = 7.43 [7.16, 7.71]	*t*(184) = 13.82, *p* < .001, *Cohen's d* = 1.02
Change in the Idea of Educational Experience (CIEE)	M = 6.24 [5.87, 6.62]	*t*(184) = 3.94, *p* < .001, *Cohen's d* = .29
Improvement in the Attitude towards Technologies (IAT)	M = 7.81 [7.44, 8.18]	*t*(184) = 12.19, *p* < .001, *Cohen's d* = .90
Improvement in Technological Skills (ITS)	M = 7.48 [7.15, 7.81]	*t*(183) = 11.82, *p* < .001, *Cohen's d* = .87
Intention to Work in On-line Learning (IWOL)	M = 7.70 [7.37, 8.04]	*t*(181) = 12.97, *p* < .001, *Cohen's d* = .96
Importance of Teacher Education in Digital Pedagogy (ITEDP)	M = 8.60 [8.31, 8.89]	*t*(182) = 21.15, *p* < .001, *Cohen's d* = 1.56
Extent to which University should Rely on On-line Learning (UROL)	M = 8.03 [7.75, 8.31]	*t*(182) = 17.78, *p* < .001, *Cohen's d* = 1.31
Degree of University e-Maturity (UeM)	M = 6.60 [6.28, 6.92]	*t*(181) = 6.81, *p* < .001, *Cohen's d* = .50

Table 5. Comparative table 1

Variable	**Average Italian University**	**Average Iraq University**	**Average Mexican University**
University Readiness to switch to on-line education (UR)	M = 8.54 [8.40, 8.69]	M = 6.95 [6.74, 7.15]	M = 6.14 [5.82, 6.47]
Technological Adequacy of On-line Environments (TAOE)	M = 7.78 [7.61, 7.95],	M = 5.91 [5.70, 6.12],	M = 7.21 [6.89, 7.53]
Previous Experience in On-line Learning (PEOL)	M = 3.45 [3.22, 3.70]	M = 4.55 [4.32, 4.78]	M = 6.36 [6.02, 6.70]
Teachers' Technological Readiness (TTR)	M = 6.97 [6.81 7.13]	M = 5.84 [5.65, 6.03]	M = 5.41 [5.09, 5.72]
Teachers' Pedagogical Readiness (TPR)	M = 6.84 [6.67, 7.02]	M = 5.79 [5.59, 5.98]	M = 5.48 [5.18, 5.77]
Workload Increase (WI) %	M = .35 [.33, .38]	M = .57 [.55, .59]	M = .58 [.54, .62]
Teachers' Time Management Capacity (TTMC) (scale -5, +5)	M = .68 [.44, .92]	M = 1.48 [1.25, 1.71]	M = .54 [.15, .92]
Educational Activity: Lecture-Discussion (EALD) (scale -5, +5)	M = -1.08 [-1.31, -.87]	M = .94 [0.69, 1.18]	M = -0.63 [-0.99, -0.26]
Educational Activity:	M = -0.96	M = 1.40	M = 0.55

Transmissive-Interactive (EATI) (scale -5, +5)	[-1.19, -.74]	[1.16, 1.65]	[0.21, 0.91]
Educational Activity: Asynchronous-Synchronous (EAAS) (scale -5, +5)	M = 1.16 [.92, 1.41]	M = 1.06 [0.81, 1.30]	M = 0.21 [-0.16, 0.57]
Educational Activity: Individual-Collaborative (EAIC) (scale -5, +5)	M = -.96 [-1.23, -.70]	M = 1.33 [1.08, 1.57]	M = -0.57 [-0.97, -0.17]
Reproducibility of Classroom Dynamics (RCD)	M = 5.64 [5.43, 5.85]	M = 6.08 [5.91, 6.24]	M = 5.58 [5.25, 5.90]
Easyness to use On-line Learning (EUOL)	---	M = 6.47 [6,27, 6.67]	M = 6.59 [6,29, 6.90]
Usefulness of On-line Learning (UOL)	---	M = 6.35 [6,13, 6.57]	M = 7.77 [7,51, 8.03]

Table 6. Comparative table 2

Variable	**Average Italian University**	**Average Iraq University**	**Average Mexican University**
Sustainability of On-line Education (SOE)	M = 5.94 [5.72, 6.17]	M = 5.87 [5.66, 6.08]	M = 7.43 [7.16, 7.71]
Change in the Idea of Educational Experience (CIEE)	M = 4.95 [4.71, 5.19]	M = 6.28 [6.06, 6.49]	M = 6.24 [5.87, 6.62]
Improvement in the Attitude towards Technologies (IAT)	M = 5.68 [5.44, 5.91]	M = 7.05 [6.84, 7.26]	M = 7.81 [7.44, 8.18]
Improvement in Technological Skills (ITS)	---	M = 7.04 [6.85, 7.23]	M = 7.48 [7.15, 7.81]
Intention to Work in On-line Learning (IWOL)	M = 5.78 [5.52, 6.03]	M = 6.33 [6.12, 6.54]	M = 7.70 [7.37, 8.04]
Importance of Teacher Education in Digital Pedagogy (ITEDP)	M = 7.25 [7.03, 7.47]	M = 6.62 [6.41, 6.83]	M = 8.60 [8.31, 8.89]
Extent to which University should Rely on On-line Learning (UROL)	M = 5.64 [5.43, 5.85]	M = 6.51 [6.30, 6.73]	M = 8.03 [7.75, 8.31]
Degree of University e-Maturity (UeM)	M = 7.49 [7.33, 7.65]	M = 5.71 [5.52, 5.91]	M = 6.60 [6.28, 6.92]

3.1 Descriptive and univariate analysis

Technological context. Overall, in Italy, despite of the number of existing on-line universities and e-learning centers, the mean PEOL (Previous Experience with On-line Learning) of the respondents was relatively low, M = 3.45 [3.22, 3.70] on a 10 point Likert-like scale (1-10). This average is even lower than in Iraq, were on-line learning is still considered a novel and experimental methodological approach. This result indicates relatively low usage of technology in Italian tertiary education, even as a support to traditional face-to-face activities. In Mexico, instead, where Learning environments like Moodle or Google Classroom have been in widespread use for quite a long time, a considerable number of teachers reported having a substantial level of previous experience with online learning.

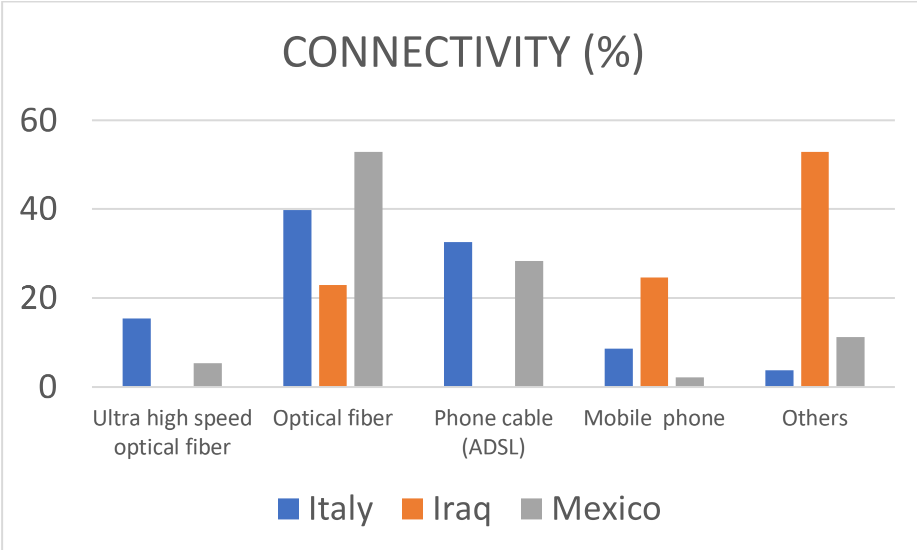

Fig. 2: Connection mode to access the Internet (%)

As far as access to the Internet, the Italian and Mexican cases look very similar. In both Countries, more than 55% of participants reported having broadband or ultra-broadband access, around 30% have an ADSL connection, and around 12% rely on smartphone data connections or other forms of Internet. In Iraq instead, only 23% of participants reported connecting through optical fiber, and the ADSL network does not exist; about 25% uses their smartphone data connection while more than 50% relies on other methods. Actually, about 48% of the latter participants connects through WI-FI access points, but we do not know to which kind of networks such access points are connected.

The contextual situation also influenced the choice of the devices used to connect to the internet. In Italy and Mexico, around 85% of survey takers use a laptop to connect online, while this percentage is 60% in Iraq. In Italy, only slightly more than 34% use a desktop computer, 43% in Mexico, and only 15% in Iraq. Tablets are not very popular (22% in Mexico, 13% in Italy and 7% in Iraq). It is not surprising that in Iraq a large majority of the individuals, 77%, use smartphones (although in parallel with the laptops). In Italy, only 12% of the respondents use smartphones to connect and perform their activities. This was likely due to the strict lockdown experienced in Italy during the time window dedicated to data collection, as teachers were working strictly from home. In Mexico, we observed a still different situation: despite the apparent adequate infrastructural level, about 60% of the teachers were using smartphones. This can possibly be ascribed either to the a less severe lockdown that allowed to connect in mobility and, as well, to a not so satisfactory quality of the internet connectivity. In fact, if we look at main issues reported, Mexican teachers reported substantial internet connectivity problems. In Italy only less than 5% percent lamented the lack of or limited availability of devices suitable for carrying out online activities, while more than 31% complained about insufficient bandwidth. This percentages almost doubled in Mexico, more than 12% complained about the obsolete devices and almost 58% about the quality of the connectivity. The latter appears to be a dramatic problem in Iraq, with 78% of respondents lamenting bad connectivity and about 14% reporting inadequate devices.

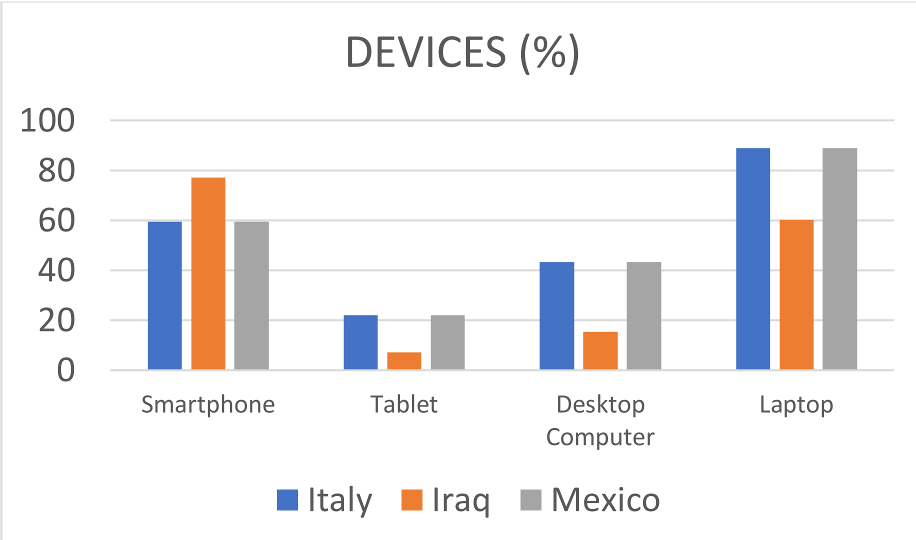

Fig. 3: Devices used to connect to Internet (%)

Readiness of the learning ecosystems. The perception about the readiness of Universities to switch from face-to-face to on-line education (UR) is much higher in Italy than in either Iraq or Mexico. As discussed in ref. [3], the higher value detected in Italy mirrors the robustness of the network and of local technological infrastructures and services, which were solid enough to allow for a full switch in a few days. The UR value detected in Iraq can be partially justified by the corresponding low value of TAOE (Technological Adequacy of On-line Environments), that seems to indicate a still immature infrastructural and technological situation. In fact, the average switching time from face-to-face to fully on-line operativeness was around two weeks. In Mexico, instead, we have observed a quite low value of UR despite a relatively high value of TAOE. The knowledge of the specific local context seems to indicate that this can be ascribed to a lack of management capability. Learning environments like Moodle or Google Classroom have been in use for a long time in the Mexican University context, and a considerable number of teachers reported having a substantial level of previous experience with these platforms (see mean value of the PEOL variable). The switching time toward the use of on-line learning environments was of the order of few days. Basically, what it seemed to happen is that the university staff have not received sufficient guidelines or have not been properly accompanied during the transition to the delivery of on-line learning processes.

The outcomes analyzed up to now show that while in western and developed countries the access to connectivity and learning environments does not represent a critical issue – at least at Institutional level – in other countries like Iraq it is still an issue. In any case, connectivity and learning environment are not enough if they are not accompanied by adequate crisis management, as pointed out by the Mexican case.

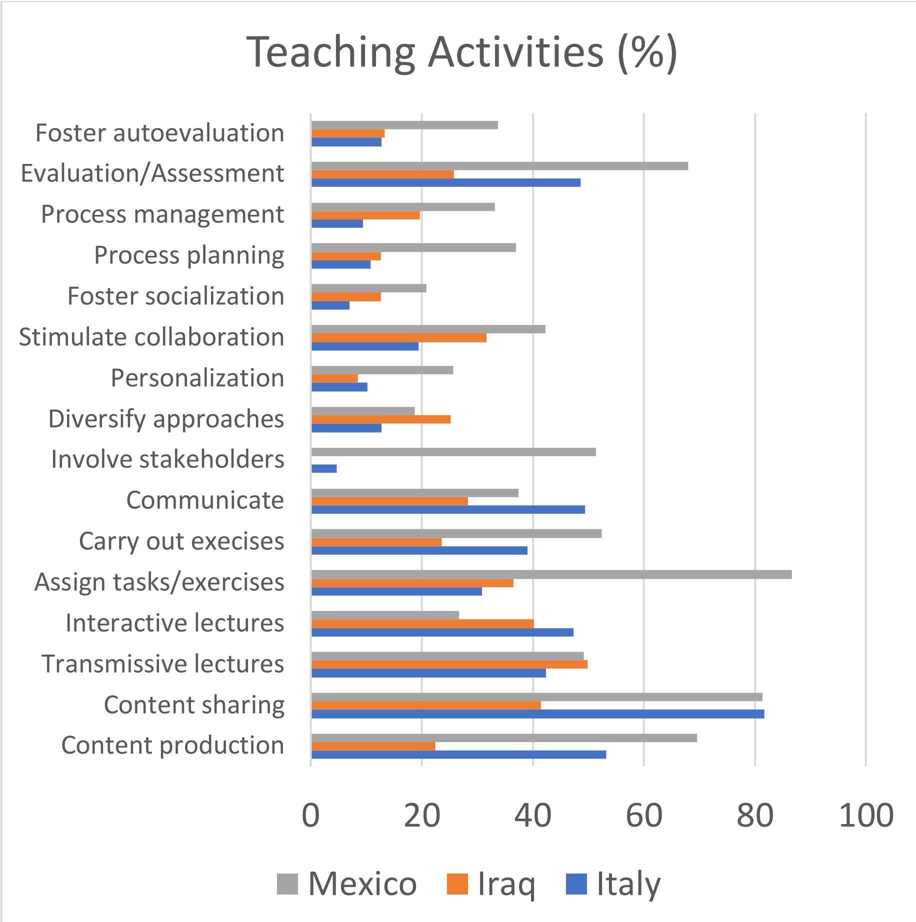

Fig. 4: Purposes for which technologies have been used during the on-line educational processes (%)

Teaching activities. The settings described above are those within which all university teachers of the three countries considered by this study had to continue to deliver the educational processes and implement the related didactic activities. To identify the pedagogical strategies implemented by the teachers, we asked them to rate the teaching activities they carried out during the lockdown along four axes: lessons vs. discussions (EALD in the above tables), transmission vs. interaction (EATI), asynchronous vs. synchronous (EAAS), and individual vs. collaborative (EAIC) – all scales ranging from -5 to +5. As shown in Table 4 we observed three different situations:

- in Italy, the respondents deemed their teaching activities to be more lecture-based (M = -1.08 [-1.31, -.87], transmissive (M = -0.96 [-1.19, -.74]), synchronous (M = 1.16 [.92, 1.41]), and directed to individuals (M = -.96 [-1.23, -.70]), outcomes that, as already seen in ref. [3] can easily be explained by the attempt to reproduce the ex-cathedra lectures dynamics and content sharing.

- in Iraq, differently, the teaching strategy and activities seem to have been more discussion based (M = .94 [0.69, 1.18]), interactive (M = 1.40 [1.16, 1.65]), synchronous (M = 1.06 [.81, 1.30]), and collaborative (M = 1.33 [1.08, 1.57]). A possible explanation for this is that teachers believe the educational concepts could be better delivered through interactive and synchronous activities than by just sending videos to students (as some respondents commented in the open questions). This approach would allow teachers to communicate with their students directly, which would help spotting out any difficulties students might have in understanding the explained concepts or assignments.

- Finally, in Mexico we detected an attitude very similar to the Italian one, although the ex-cathedra lectures seem to be more interactive; in fact, teaching activities tended to be more lecture-based (M = -.63 [-.99, -.26]) but also more interactive (M = 0.55 [.21, .91]), slightly more synchronous (M = .21 [-.16, .57]), and directed to individuals (M = -.57 [-.97, -.17]).

If we look at the purposes for which technologies have been used by teachers, fig. 4, we note that Mexican teachers tend to have a larger percentage of individuals that use technologies for multiple purposes and thus comparison among the three different cases should be done considering the relevance of each function for a specific group of respondents. Mexican and Italian teachers, as expected from the previous observation, tend to carry on mainly the same typology of activities: content production and content sharing, carrying out exercises (and exercises assignment in the Mexican case) and student evaluation. In the case of Mexico, it seems that collaboration is somewhat more stimulated than in Italy. As far as the Iraqi case, we can observe that the activities are less content centered and more lecture centered. Transmissive lectures are prevalent but interactive lectures are also quite important. Additionally, Iraqi respondents report stimulating collaboration, diversifying pedagogical approaches, assigning exercises, and evaluating students. Although teachers in Iraq believe, as previously mentioned, that having synchronous and interactive sessions would better benefit the educational process, the lack of standard tools (e.g. applications and software) and poor network could hinder this process. The absence of a good and stable network would make it difficult to hold an online lecture, as some comments stated, hence teachers tended to carry out transmissive sessions. Additionally, another difficulty raised by respondents is that some students are unable to access the Internet due to a lack of funds, which makes it more important to assign collaborative activities to reduce the load on students.

Looking at assessment modes, the Italian situation appears very peculiar, as it relies almost completely on synchronous oral interviews (around 84%). Individual assignments and online tests were used by less than 18% of the respondents, while collaborative and group assignments were used by less than 12% of the university teachers. This result can possibly be explained by a few concomitants elements: a) the good quality of the infrastructure that allowed a large majority to use video interaction and conferencing; b) the limited technological or pedagogical preparedness of teachers or their intention to minimize the effort and time needed to design new and innovative activities suitable for the new setting; c) the low trust in assessment modes that do not allow a "direct" verification of students' preparation.

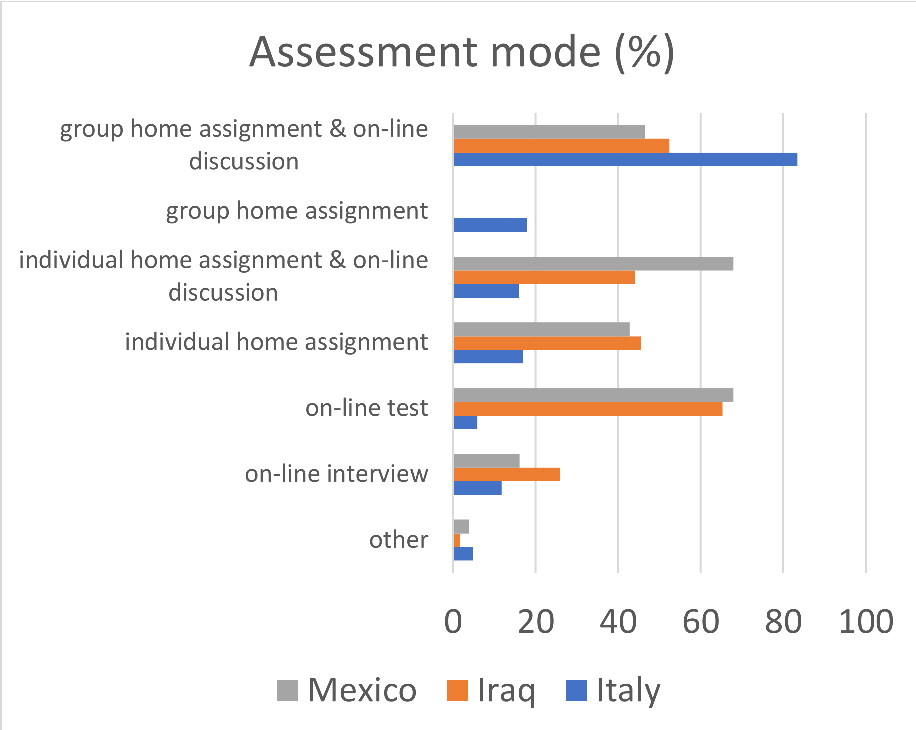

Fig. 5: Assessment modes used during the on-line educational processes (%)

As far as the assessment is concerned, the situation is very similar in Mexico and Iraq: in both countries teachers relied mainly on on-line tests and home assignments (possibly with on-line presentations and discussions). It is interesting to note that, coherently with the characteristics of the didactic activities discussed above, in Iraq group assignments are more popular than individual assignments. This could be easily explained by a lack of funds which would directly affect the availability of devices for students, which makes the use of group assignments more sensible. This would help reduce workload and burden on students and, at the same time, promote the sharing of resources and knowledge. In fact, it would also reduce workload on teachers, as they would need to assign and consequently assess less assignments' sheets.

Workload and time organization. This comparative study shows that teachers, independently from the operative context, perceive the on-line activities as more time consuming than face-to-face ones: the working load increase, WI, takes the value of .35 in Italy (an increase of 35%), .57 in Iraq and .58 in Mexico. The lower value observed in Italy can possibly be ascribed to the limited propensity of Italian teachers to explore novel strategies and the tendency to reproduce standard ex-cathedra lectures.

Fig. 6 and Fig. 7 show the time spent on-line by university teachers to deliver distance learning and the overall time-based workload to support and deliver distance learning.

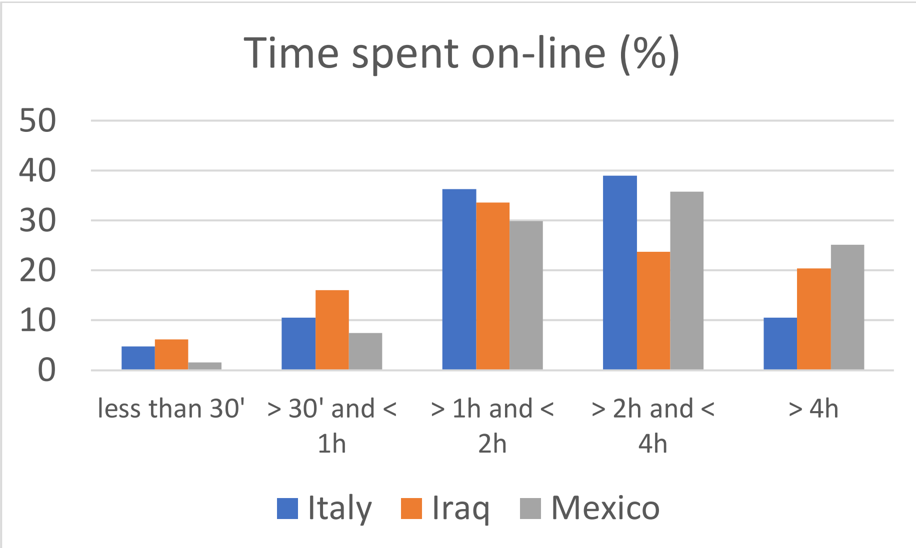

Fig. 6: Time spent on average on-line by the university teachers (%)

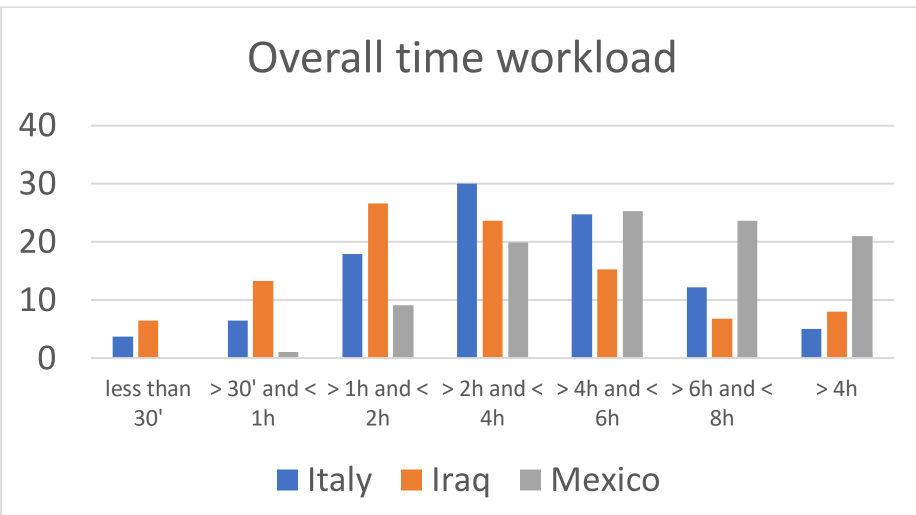

Fig. 7: Overall time workload (spent on-line and in preparing on-line activities (%)

We estimated an average time spent in delivering on-line activity quite similar for Italy and Iraq – 139 and 142 minutes respectively – and half an hour longer for Mexico (170 minutes). As far as the overall time-based workload to support and deliver distance learning we estimated an average 226 minutes for Italy, 191 minutes for Iraq and 333 minutes for Mexico. This means that in Mexico the perceived increase of working load seems to be correlated to the time spent to maintain in place and deliver the on-line education process. In Iraq, on the other hand, it is possibly more related to the intensity of the effort than to its time duration.

More aspects could be related in the case of Iraq, as reported by some respondents, such as the need to produce different lecture formats (i.e. PDF, videos) alongside the on-line lecture to discuss the given material, which would take extra time as recording videos is time consuming. This, however, would allow students with limited connectivity to better access lecture content. This, in addition to the fact that distance learning is relatively novel in Iraq, would partly explain the overall workload increase.

In any case, despite of the perceived increase of the working load, in teachers' opinion, the operational conditions experienced under the pandemic induced a higher self-reported capacity to manage their own time with respect to pre-COVID outbreak conditions (much higher in Iraq than in the other two countries) see (TTMC) in Table 5.

A look into the future. Through our survey we also tried to stimulate a very preliminary reflection about possible future developments.

As already observed in a previous publication [3], it is quite clear that Italian university teachers did not change their idea on the educational experience (CIEE) while, on the other hand, the Emergency Remote Education experience seems to have provoked a more in depth reflection in both Iraqi and Mexican university teachers. The outcomes of such reflection and of the overall experience seems to be positive with respect to the on-line learning processes, especially in Mexico. The improvement in teachers' attitudes towards technologies (IAT) and in their technological skills (ITS) is quite high in all three countries. On the other hand, in Iraq teachers seem to be less confident than in Mexico in the e-Maturity level (infrastructure, competence and vision) of the universities and, accordingly, the perception of sustainability of on-line education is lower. This is despite a positive attitude toward the involvement in on-line learning (IWOL) and its adoption by the universities (UROL). It is not easy to explain the relatively low value associated in Iraq to the need and importance of teacher education in digital pedagogy (ITEDP). However, this could be due to the fact that university teachers in Iraq were not very familiar with distance-learning at the time of this study, as it is considered a relatively novel experience. Perceived e-Maturity appears to be very high in Italy too, despite other parameters getting low values. This could be due to a large part of teachers still being fond of ex-cathedra lectures and of the traditional teaching approach. On the other hand, the technological infrastructures and applications are deemed to perform sufficiently well to allow for the transfer of the classroom dynamics to the on-line modality, despite some expressive and communication difficulties.

Not surprisingly, in Mexico a large majority of the teachers, 65.6%, would prefer to continue teaching in a blended configuration, while 9.7% would prefer teaching fully on-line and only 24.7% would come back to f2f configuration. Supporters of f2f education are 49% in Iraq and 50% in Italy. One may observe in any case, that the result that 33% of teachers would prefer the blended configuration and 18% would prefer the fully on line one, is quite surprising for a country like Iraq where infrastructures are not so well developed and on-line learning is at a very initial stage. Differently, in Italy we observe a more conservative attitude. Nevertheless, half of the Italian teachers would prefer, and feel ready, to continue in blended configuration (43.5%) or fully on-line (6.5%), which are higher percentages that what we would have expected before the COVID pandemic. This could mean that the pandemic has left a mark, and the attitudes toward on-line learning and technologies may have somewhat changed.

The scenario and data described above, however, do not allow us to clearly identify the possible relationships among the investigated variables, nor their possible causal dependencies. In the next sections we will try to shed light on this aspect.

3.2 Causal discovery

Network analysis is a broad collection of tools for visualizing and analyzing relationships between sets of variables. Network analysis is suited for highly explorative studies, as networks are identified bottom-up from data, without the tight specification of *a priori* models and constraints required by, from example, structural equation modeling. A typical network analysis could entail, for example, the computation of regularized partial correlation networks, which could then be presented as a graph of associations between variables [11] [12]. This can provide a comprehensive picture, allowing a quick comparison among networks and highlighting commonalities and trends. Additionally, this kind of analysis can be taken one step further using causal discovery algorithms.

Causal discovery is based on Pearl's concept of d-separation [13], 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, a so-called 'V-structure': two variables that are connected to a third one, but not to each other. So, for example, Y is connected to both X and Z, but X is not connected to Z. If, when conditioning on Y, we observe that X and Z are not independent anymore, we can orient both the connection between Y and X and the connection between Y and Z towards Z. The reason we can orient that edges is that 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, X ← Y → Z. Therefore, the only possible directed configuration that explains the result is X → Y ← Z. Directing those connections puts new constraints in place, which can be used to further infer the direction of connections in the graph in an iterative process.

This procedure, however, presents the important drawback of relying on strict assumptions, which are rarely met in real-world data. One of those is that, in order to estimate networks accurately, there should be no hidden variables (and especially hidden common causes) in the network. Therefore, since this assumption is often violated, causal discovery networks should be interpreted tentatively, as 'suggestions' rather than factual results. However, in a purely exploratory analysis such as this one, they can aid and guide interpretation of results.

We performed causal discovery using the PC algorithm with α = .01 and an order-independent and non-conservative version of the algorithm (see [14] for details). This way, we were able to identify the structures reported in figures 8-10.

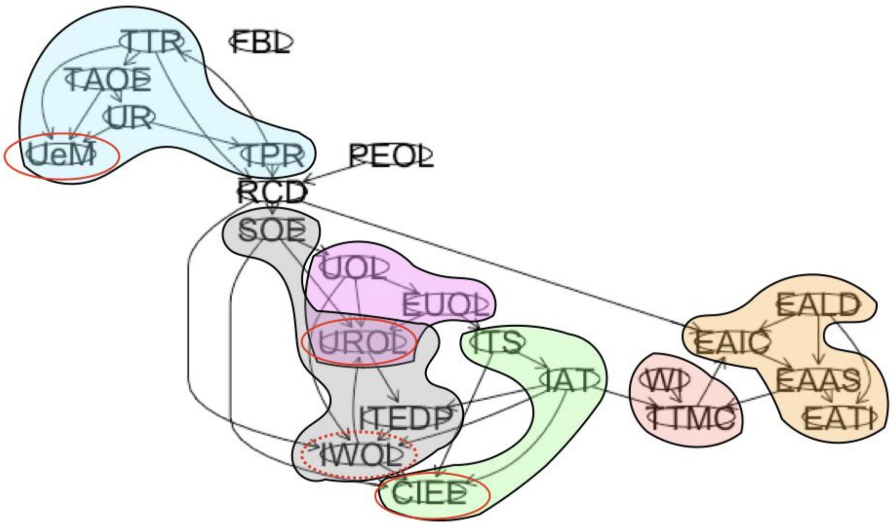

Fig. 8. Causal structure of the main variables considered in this study: Iraqi case.

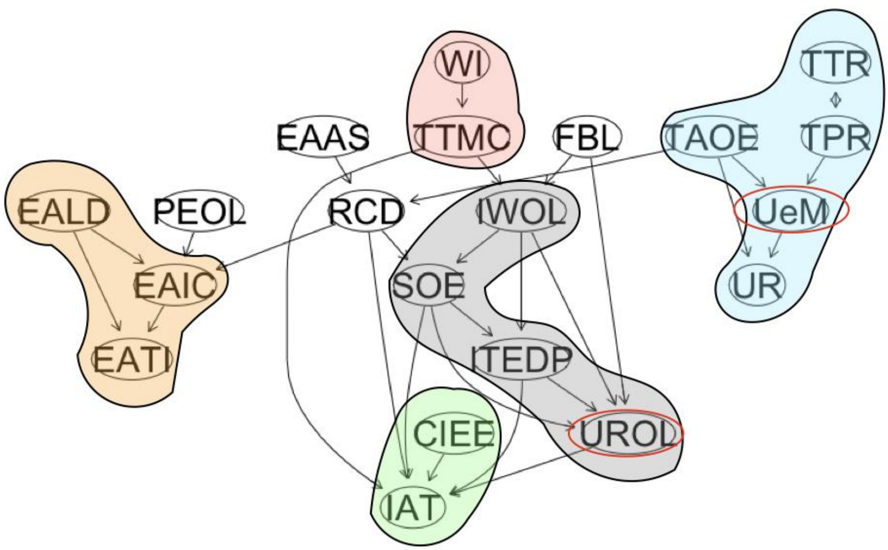

Fig. 9. Causal structure of the main variables considered in this study: Italian case.

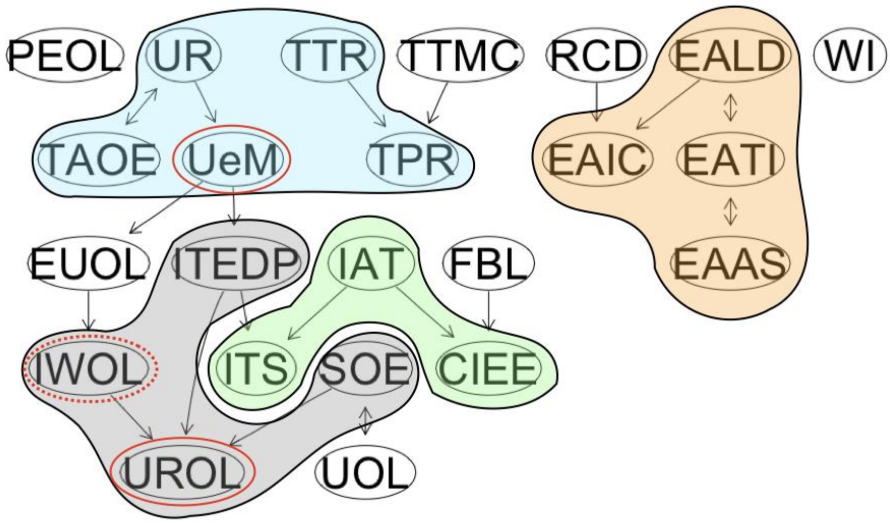

Fig. 10. Causal structure of the main variables considered in this study: Mexican case.

As expected, due to the limited number of the respondents, in the Mexico case we observe a sparser causal network, with unconnected clusters of variables. It is also important to note that the Iraqi network presents several cycles (for example: EAIC causes EAAS, which causes TTMC, which causes EAIC). Therefore, it's not generalizable to a directed acyclic graph. This is a strong indication of violated assumptions; it's highly likely that there are relevant omitted or hidden variables, e.g., a common cause of EAIC and EAAS. Thus, all interpretations regarding the Iraqi network should be interpreted with special caution.

Colored areas highlight clusters of strongly correlated variables that are identifiable in all three networks. The blue area identifies the variables that contribute to the e-maturity of the universities and that, in turns, contributes to a cluster of variables concerning future expectation, in grey (the e-maturity–future expectations connection is direct in the Mexico network, and mediated by the reproducibility of classroom dynamics in the other two networks). Future expectations seem related to the cluster IAT, ITS, CIEE, in green. This cluster relates to attitudes towards technology and digital education, and seems to be influenced by future expectations (in the Iraqi network, the influence between these two clusters is reciprocal). In orange, we can see a cluster constituted by the characteristics of the didactic activities (e.g., whether the activities proposed were synchronous or asynchronous, transmissive or interactive…), which tends to be connected with the reproducibility of the classroom dynamics, RCD, but is otherwise at the periphery of the network and exerts little influence on other variables. In the case of the Iraqi and Italian network, we can also identify a pale red region that includes the strongly related variables TTMC (teachers' time management capacity) and WI (workload increase).

Variables that can be considered local or final terminals of the causal network are evidenced by a red ellipse.

Getting into the details of the causal network we can observe:

• that the previous experience in on-line learning, PEOL, in this situation did not seem relevant (not connected or connected to different variables as side contribution);

• the intention to use blended learning in the future, FBL, is not found, as one could have expected, at the bottom of the causal network; in the university cases investigated by this work, FBL is either unconnected (Mexico) or appears to be an a priori decision that may influences different variables (Italy, Iraq);

• the reproducibility of classroom dynamics, RCD, tends to assume a central position; it acts as a bridge between the blue and grey (SOE variable) areas in both the Iraqi and the Italian cases and in all cases it seems to influence the individual-collaborative characteristic of the educational activities;

• the perceived increase of working load, WI, seems to influence teachers' time management capacity, TTMC, while the overall location of the pale red area in the overall structure does not seem to have a stable position;

• the cluster of variables (light blue) that define the perceived state of the art – infrastructure, technologies and humans – and, thus, the perceived e-maturity of the universities is situated in an apical position with respect to the causal chain and, as we have seen, consistently influences the cluster of future expectations (grey area); however, the internal causal connections among the variables of the blue area and the way in which the blue and the grey area are connected changes from case to case;

• the characteristics of the didactic activities (orange area) and in particular EAIC, as seen above, tend to be influenced by the capability to reproduce classroom dynamics; as far the internal dynamics of this area, it seems that the transmissive-interactive balancing of the didactic activities, EATI, can be considered a local terminal;

• the green area can be considered one of the terminal areas of the causal chain, and in particular the variable "change in the idea of educational experience" (CIEE);

• the other terminal area is the grey one, including all variables related to future expectations; as expected, here we observe some variables that appear to be effects rather than causes – most consistently, the extent to which university should rely on on-line learning (UROL) and the intention to work with on-line learning (IWOL); the casual network more consistent with the Authors' expectations is the one observed in Iraq, where the perception of sustainability of the on-line learning, SOE, contributes to IWOL which, in turns, affects UROL as well as the perceived need of training in digital pedagogy, ITEDP and CIEE; in the case of the Mexican survey, we observe a quite similar trend but the limitation in the number of respondents does not make us as confident in discussing the details of the causal network; in the case of Italy, as already noted in [3] we observe paths that go in the opposite direction compared to our expectations (e.g., intention to use blended learning appears to be a cause, rather than as effect). This could be tentatively interpreted as a possible sign of preconceptions on the parts of participants: in fact, according to the network, it is the intention to adopt a blended learning configuration, FBL, and to work with on-line learning, IWOL, that determine the sustainability of the on-line didactic activities, SOE, and this in turn ITEDP and finally UROL. We can also note that in the Italian case it is CIEE causing IAT and not the contrary - which would be more consistent with theoretical considerations.

To conclude this analysis, we wish to underline that in the Iraqi case we can observe also a structure, in violet, that reproduces the well-known TAM, with the easiness of use of the on-line learning, EUOL, and the usefulness of the on-line learning, UOL, that contribute to determine the extent to which university should rely on on-line learning, UROL. It is important to note that this structure has not been observed in the other two cases because in the Italian case these two variables were not investigated and in the Mexican one, most likely, because the network is sparser due to the smaller sample. In any case, one should also stress that the TAM-like structure observed in the Iraqi case appears not to be essential to the network, as the relationships between connected variables are roughly the same in the Italian and Mexican network.

4 Discussion and future work

Due to the similarities among the three networks of variables that have been derived for the three ecosystems studied in this work we have investigated their network similarities.

We have performed such investigation by using DELTACON [15] as a measure of network similarity. It takes into account edge weight and the relative importance of connectivity changes, and where 0 denotes complementary networks and 1 denotes identical networks, we observe DELTACONs of .827 (Iraq - Mexico), .828 (Italy - Mexico), and .876 (Iraq - Italy)[1]. These values indicate substantial overlap between the networks (somewhat lower, as could be expected, when comparing the sparser Mexico graph with the other two).

Such results, together with the causal networks showing similar features, led us to propose the model represented in fig. 15 – MAETI – that attempts to catch the main structural features (macroblocks) of such networks and their causal relationships. Basically, we have first identified an area related to the perception of the technological setting that is strongly related with the e-maturity of the context and includes infrastructures, technologies, competences, capability to react and visions. The perception about the technological setting is one of the main elements capable of influencing any change of mind about the perception of process modification fostered by the adoption of new technologies (or of modified context, or simply of new technologies) and of the individual relationship with the new technological setting (or, again, simply new technology). The change in mind and of the perception about technological based processes or technologies is affected also by what we may call forces that play a role at individual level and that are related to perception of difficulties and advantages (like the increase in the workload, the capability to organize their own time, etc.). The latter may also affect the characteristics of the

[1] As DELTACON requires the same nodes to be present in the networks, DELTACON computation ignores the variables (UOL, ITS, and EUOL), which were not collected on the Italian sample.

activities, in this specific case educational activities. Of course, a technological context cannot be represented only by a static "picture" (the perception of the setting) and the on-going processes should be considered: in this study, they are represented by the classroom dynamics. This is the possible reason why the variable RCD has assumed a bridging role in the causal networks represented in figures 8 and 9 and why it influences the educational activities through EAIC. It is also important to stress that the on-going processes can also be considered the place of the confrontation between innovative and conservative forces, between those that wish to innovate to improve the process and those that prefer to remain in their comfort zone and tend to develop a contrastive attitude toward technological innovations.

At the bottom of this macrostructural model, as a target, we find the future intentions area, which includes intentions about the use of technology-based processes (or technology), about the individual commitment and, possibly, about the need for specific training.

It is worthwhile to note that we have represented as overlapping areas those related to the change in mind about technologies, processes and the personal interaction with the technological environment (or technology) because from the data we collected we are not able to understand if, for example, the change in attitudes about processes should be considered as an additional target of the causal network.

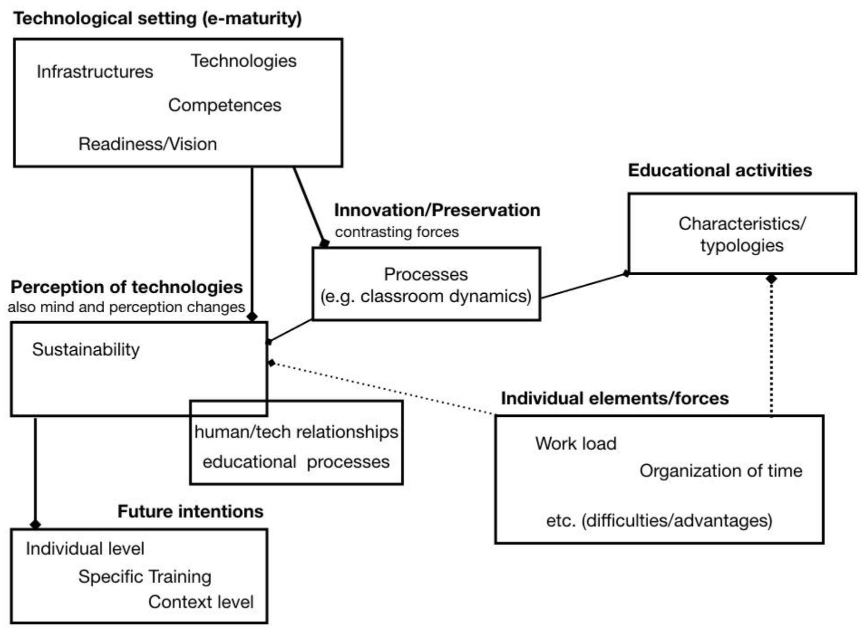

Fig. 11. A sketch of a tentative Model for Attitude to get Engaged in Technological Innovation (MAETI)

At this point, since we have been able to test the relevance of the factors considered in the TAM model, to better contextualize the model that emerged bottom-up from our extended investigation, it is worthwhile to compare it with the very popular Technology Acceptance Model (TAM) in its extended version applied to e-learning, described in ref. [6], and sketched in fig. 12.

Comparing fig. 11 and fig. 12 we can see that there are similarities and differences. The perception of the *system characteristics* can be related to the *perception of the technological setting* although the latter is more extended in scope, being not restricted to a specific technology but encompassing all aspects of the e-maturity of a given context. With the same limitation in mind, we can map the *individual factors* to the *individual elements/forces*. With the same caution, we can map the *induced change in the perception about technologies, process and individual-technology interaction* can be mapped to the *attitude toward using* and the *future intentions* to the *intention to use*. The *actual use* has not been investigated in our surveys.

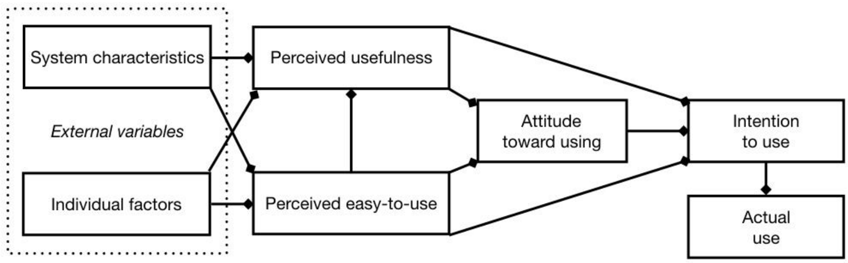

Fig. 12. Sketch of the extended Technology Acceptance Model (TAM)

Apart from the different extension of the systems/ecosystems considered by the models of figures 11 and 12 there exists two main differences: a) in fig. 11 the processes are deemed relevant to complete the representation of the ecosystem to include the dynamics; b) *individual elements/forces* and *perception about the technological setting* influence directly the future intentions and need not go through variables like *perceived usefulness* or *perceived ease of use*, as discussed when analyzing the Iraqi causal network (see fig. 8). As a tentative explanation of the scarce relevance of variables like UOL and EUOL in our investigation, we can take the dimension and complexity of the ecosystems we have been investigating. In fact, by increasing the dimension and the intrinsic complexity of the system under investigation and, as well, the complexity of the interaction between individuals and the ecosystem, concepts like *perceived usefulness* and perceived *ease of use* tend to blur and lose their concentration power and mediation capability.

We would like to underline that MAETI has emerged bottom-up from our explorative research aimed at investigating the effects caused by the transition to the on-line learning imposed by the pandemic. Because of this, MAETI could be considered a first attempt to systematize the research on attitude to get engaged and involved by systemic technological innovation. However, it would need further investigation and validation. For example, possible research directions may include: i) the study of the emergence of similar causal structures from data collected involving other categories of actors, like the students; ii) the identification of possible hidden variables/factors from the analysis of the texts collected through open questions with the aim to better identify the most relevant ones for each investigated area; iii) the preparation of more focused questionnaires aimed at validating the model in the same and other contexts; iv) the implementation of modified questionnaires aimed at investigating the relevance of the factors that have been considered by other models of technology acceptance (e.g. United Theory of Acceptance and Use of Technology - UTAUT, Concerns-Based Adoption Model - CBAM, etc. [17]) together with the potential interplay of such factors with the structures of the causal network emerged in this work and, thus with MAETI. In fact, the sudden outbreak of the epidemic generated a unique situation, not reproducible and never occurred before, that could not be investigated by means of a priori defined models and required the use of a heuristic and bottom-up approach to grasp the intrinsic nature of the phenomenon. Nevertheless, once a potential model emerged – the MAETI – and when a "new normality" will develop, more finalized studies could be carried on and the interplay between emerging and preexisting models and factors could be investigated in more details to fill a potential gap in the knowledge a provide a better framework of reference for the MAETI.

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