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Educational innovation in higher education: engineering students' experiences of Emergency Remote Teaching

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ABSTRACT

Research on concerns about Emergency Remote Teaching has focused on teaching and management strategies, with some studies considering learners' satisfaction, reactions, learning and overall acceptance. The present case study, based on a survey on 3,183 undergraduate and postgraduate learners, aimed at investigating engineering students' self-reported experiences of the Emergency Remote Teaching. It identified the empirical factors characterising such experience and the predictors of the students' responses. Moreover, it focused on their reaction to the innovation in teaching and learning methodologies in an extreme scenario. Quantitative methods, like confirmatory factor analysis and factorial ANOVA, were adopted to analyse data. Our findings highlighted that engineering students assessed their overall online learning experience of Emergency Remote Teaching slightly negatively. This evaluation concerned their opinion about three factors which achieved different assessment. These results did not appear to depend on the learners' gender or their educational level of degree study, while the academic year of attendance seemed to influence their opinion on teaching. Moreover, the change in the learning approach experienced in the passage from bachelor to master's programmes was discovered to be a further predictor which might be more critical for females than males. Finally, implications for policy makers and higher education institutions for online learning in the post-pandemic scenario are discussed.

PUBLIC INTEREST STATEMENT

The Covid-19 pandemic imposed on universities an abrupt switch from in-presence to distance learning. This case study, based on a survey of 3,183 Italian undergraduate and postgraduate learners, aimed at investigating engineering students' self-reported experiences of the Emergency Remote Teaching. It identified the empirical factors characterising such experience and the predictors of the students' responses. Moreover, it focused on their reaction to the innovation in teaching and learning methodologies in the context of an extreme scenario. Our findings highlighted that engineering students assessed their overall online learning experience slightly negatively. Female and male, and undergraduate and postgraduate students gave substantially the same evaluation, while the academic year of attendance seemed to influence their opinion on teaching. Moreover, the change in the learning approach that learners experienced in the passage from bachelor to master's programmes was discovered to be a further predictor which might be more critical for females than males. These results may be of interest to policy makers and higher education stakeholders interested in providing inclusive and sustainable online teaching and learning.

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1. Introduction

1.1. Distance learning, online learning, emergency remote teaching

As a consequence of the COVID-19 pandemic, distance learning was the most widespread modus operandi implemented by university students across the globe in the first half of 2020 (Marinoni et al., 2020), which was not a novelty, having already been implemented and investigated for decades (Holmberg & Förlag, 1960; Lam et al., 2021; Martin et al., 2020; Means et al., 2014; Moore, 1973; Peters, 1971; Rodrigues et al., 2019). Contrary to what one may think, distance learning does not correspond to a unique educational approach. Rather, it includes a broad variety of learning and teaching strategies (Holmberg, 1980; Keegan, 1980) thanks to the wealth of technical media which bridge the spatial distance between the instructor and their students. According to Saykılı (2018, p. 5), distance learning requires the physical separation of teachers and learners to plan and structure learning experiences through two or multi-way communication channels.

Among these diverse approaches, online learning refers to an educational experience where lectures and courses are offered online. It seems to have been used more than others by academic institutions during the first months of 2020 (Chaudhry et al., 2021; Gonzalez et al., 2020; Govender & Mpungose, 2022; Ives, 2021; Shahzad et al., 2021; Sing Yun, 2023; Sohil & Sohail, 2022). In this panorama, Italy played a special role probably owing to its being the first Western country hit by the COVID-19 pandemic and one of the most seriously affected by its huge wave (Crawford et al., 2020). From this point of view, the Italian Politecnico di Milano was almost a pioneer switching its educational approach from face-to-face to online in just a few days.

In a systematic literature review which examined studies published from 1988 to 2018, Singh and Thurman (2019) pointed out that online learning, a locution employed since 1995, encompasses at least forty-six distinct definitions and eighteen synonymous expressions, like web-based education or e-learning. Analysing these definitions, Singh and Thurman argued that common and indispensable elements which characterise online learning are the use of the internet, a synchronous or an asynchronous environment and a students' interaction with lecturers and other learners which does not depend on their physical location. Furthermore, several studies have highlighted that its effectiveness is closely related to scrupulous educational design and planning (Branch & Dousay, 2015; Means et al., 2014).

It should be pointed out, however, that online learning does not imply that all the activities are online. In a blended model, for instance, the ratio between in-presence and distance learning ranges from 30% and 79% (Müller & Mildenberger, 2021). An integrated and distributed model of blended learning which employs educational technology to promote authentic student learning experiences is described in a recent review study. This focuses on blended learning in the context of higher education and analyses the rationale for this instructional design in a university context (Istenič, 2024).

According to Hodges et al. (2020), to conceive, plan, arrange and deliver an online academic course requires at least from six to nine months. Before the Covid-19 pandemic almost all the educational institutions around the world offered traditional face-to-face courses but the sudden transition to distance learning imposed by the health crisis did not allow time to rethink those courses. Consequently, the distance learning which was largely adopted by universities on account of the hurried change of education approach imposed by the COVID-19 pandemic, cannot classify as online learning. Hodges et al. (2020) first named this type of learning as Emergency Remote Teaching (ERT) and their proposal has been widely used in the scientific literature on this issue (Bond et al., 2021; Bozkurt & Sharma, 2020; Colclasure et al., 2021; Misirli & Ergulec, 2021).

1.2. Background

Not surprisingly, ERT has been the subject of a massive number of investigations throughout the world. Bond et al. (2021) reviewed, for instance, 282 primary empirical studies whose authors originated from 73 countries across all the continents, though spread in different percentages, as already highlighted in previews studies (Bond et al., 2019). Bond et al. (2021) highlighted some common distinguishing features of these studies, which could also represent significant limitations.

A first distinctive characteristic was that 236 out of 282 investigations (83.69%) were categorised as quantitative or mixed studies. Nevertheless, 227 studies employed only descriptive statistics to analyse the collected data, without any use of inferential or correlational statistics. As a result, a meaningful number of these studies should be classified as descriptive of ERT, because they did not allow to infer any conclusion about it. In other words, these studies could barely cast light on factors which influenced the student and the instructor experience of ERT.

A second peculiar feature regarded the sample sizes, which only in 25.2% of the studies included more than 400 participants, namely the threshold used to consider a group large (Bond et al., 2021, p. 11), while 16.3% of the articles used fewer than 26 individuals. In this perspective, our research addressed this limitation since it involved 3,183 participants. Finally, 157 out of 282 studies (55.67%) did not report any information about the period of data collection. However, considering that this review included comprehensive studies published between January 2020 and October 2020, one may argue that the analysis and results covered merely the initial phase of ERT.

With reference to the main results highlighted by the studies conducted during the COVID-19 pandemic, several of them focused on students' perceptions of ERT. In a research involving 578 physics students from five academic institutions in Austria, Croatia and Germany, it has been pointed out that students' subjective learning achievements were positively correlated with self-organisation skills and communication abilities. Moreover, freshmen highlighted notably lower learning outcomes than older students (Klein et al., 2021). A generalised conclusion appears to be that ERT was essential to continue the learning pathway during the sanitary emergency and was useful from this point of view; nonetheless, it was deemed less effective than face-to-face learning and teaching (Almahasees et al., 2021; Chakraborty et al., 2021; Gonçalves et al., 2020; Marzoli et al., 2021; Muthuprasad et al., 2021; Owusu-Fordjour et al., 2020; Petillion & McNeil, 2020).

In a study involving 804 Polish medical students, Bączek et al. (2021) interestingly discovered that learners judged online and in-presence learning as equivalent with reference to their capability to generate knowledge. On the contrary, the same learners considered the former less effective than the latter in terms of enhancing skills and social competences. However, it should be considered that ERT was frequently implemented during the quarantine period imposed in many countries in order to limit the SARS-CoV-2 infection. Brooks et al. (2020) pointed out that the experience of a forced lockdown caused significant negative psychological effects, like annoyance and a post-traumatic stress syndrome, and is likely to have affected the students' adverse judgment on ERT. Many studies, after all, indicate that remote learning increased students' anxiety and decreased their engagement, interest and interaction with reference to academic life and experience (Browning et al., 2021; Cao et al., 2020; Chakraborty et al., 2021; Chen & Lucock, 2022; Petillion & McNeil, 2020; Sankhi & Marasine, 2020).

Furthermore, a number of studies highlighted the main challenges observed in the transition to online learning (Chowdhury et al., 2024; Doyumğaç et al., 2020; Sing Yun, 2023). According to W. Sing Yun (2023) they could be grouped into three sub-clusters, related to technological tools, digital skills and competency, and attitudes of acceptance. Finally, in an interesting research based on a qualitative methodology, Doyumğaç et al. (2020) identified many important barriers as well as facilitators for distance education during Covid-19.

1.3. Introduction to the present study: purpose and relevance

In this study we investigated the ERT implemented at the Politecnico di Milano, a university in Italy which offers degree programmes in Engineering, Design and Architecture. Both in the second term of the academic year 2019–2020 and in the first term of 2020–2021 Politecnico di Milano adopted remote teaching in a synchronous learning environment, even though the recording of lectures and exercise sessions was available to the students at any time. In the second term of the academic year 2020–2021, however, students could freely opt for distance or blended learning (online lectures, online exercise sessions or in-presence at their own choice) in the context of a synchronous environment and with the opportunity to watch the recorded lectures and the exercise sessions. As a matter of fact, not only did the pandemic cause a massive employment of technology which allowed the students to continue their learning path, but it forced the instructors to redesign their traditional lectures. Indeed, the academic courses attended by these Italian

learners before the pandemic were largely based on traditional lectures, with only a few exceptions (Bozzi et al., 2021; Bozzi et al., 2021; Bozzi et al., 2018, 2019; Zani & Bozzi, 2018).

Moreover, it is worth mentioning the paramount role played by the Bologna process in Italian university innovation. The Bologna process refers to the path that twenty-nine European countries undertook to sign the Bologna Declaration at the University of Bologna in June 1999. This agreement aimed at improving coherence in the higher education systems across Europe and established the European Higher Education Area. As a consequence, to harmonise the academic Italian system to those of other European countries, our government launched a radical reform of the university system in November 1999 (Gazzetta Ufficiale, 2000) and a '3 + 2' unitary two-tier system (Bologna process cycles) was introduced in Italy. A 3-year First Level degree, equivalent to the Bachelor degree of other countries, followed by a 2-year Second Level degree, corresponding to the Master's degree, replaced the previous 1-tier system whereby academic programmes lasted from a minimum of four to a maximum of six years.

In this context, the present research distinguishes itself for its wide use of inferential statistics to complement descriptive statistics, as well as its covering different stages of ERT. Firstly, we focused on dimensions of distance learning which emerged from empirically validated constructs and on student self-reported opinion on pre- and post-pandemic teaching. Secondly, we considered the students characteristics as predictors of their responses to the above mentioned factors. On the basis of the constructs validation, the students' profiles were used to understand the nuances in their experience. Thirdly, our inquiry covered both the initial phase of ERT, and the academic courses held in the academic year 2020–2021 after the course instructors' training programme designed by Politecnico di Milano.

Although during the pandemic many teaching practices consisted of a simple transposition of 'traditional' lecturing with the sole mediation of videoconferencing systems (Williamson et al., 2020), the massive use of technology has been an impressive innovation compared with the previous scenario in academic institutions. Therefore, a comparison between pre- and pandemic or post-pandemic approaches based on students' evaluation of teaching would yield relevant information. The high number of participants (3,183) in the present case study ensures a wide sample, which was likely to shed further light on learner perception of ERT and may pave the way for further research on both students' experiences of ERT and how they react to a notable didactic innovation.

2. Materials and methods

2.1. Research design

Owing to the cyclical worsening of the health emergency, Politecnico di Milano adopted remote teaching as the only education approach which was implemented in the second term of academic year 2019–2020 and complemented it with in-presence exercise sessions and workshop activities in the following academic year, until July 2021. This approach was supported by a strategy tailored for the professoriate. Indeed, the METID Center, a Politecnico di Milano task force focused on innovation in teaching and learning, organised about 70 sessions attended by more than 7,500 lecturers, where several issues were dealt with, like virtual classroom activation, support of student motivation, management of groups, online assessment strategies and review of the scientific literature on these topics.

At the end of the second term of the academic year 2020–2021, a questionnaire was submitted to approximately 40,000 Politecnico di Milano students enrolled on Architecture, Design and Engineering. It is worth emphasising that some learners were undergraduates, enrolled on bachelor programmes, while others had already achieved a bachelor degree and were enrolled in master's programmes. Henceforth, the former will be named bachelor students (BS), and the remainder master's students (MS). The questionnaire, which was illustrated in previous papers (Bozzi et al., 2023; Mazzola et al., 2022, 2023), consisted of 66 items across 6 sections, and focused on different latent variables as well as socio-economic information about the students; 3,920 learners volunteered to participate in this survey and gave explicit written consent to using the collected data for research purposes. In this study, however, we considered only the section devoted to remote teaching, which investigated the participants' perception of its difficulties, its organization and effectiveness and the instructors' assessment. On account of the procedure adopted for involving

the students in this study, the sample may not be considered as a representative cross-section of the Italian learners enrolled on Architecture, Design and Engineering or the Politecnico di Milano students.

We investigated the possible different opinions between learners enrolled on Architecture and Engineering and the interaction between the independent variable 'faculty' and 'gender' (Bozzi et al., 2023). In the present case study, thus, we focus on 3,183 learners attending engineering programmes, as these students made up more than 80 percent of the sample. Moreover, the engineering students' opinion was particularly interesting due to the fact that a sector like engineering would need laboratory activities, but these activities could not be carried out during the pandemic, nor were they generally replaced by virtual laboratory.

Furthermore, owing to the huge amount of data, in the present paper we analyse only one of the aforementioned constructs, i.e. the engineering students' evaluation of the online learning strategy carried out during the health emergency, which was investigated through 14 out of 66 items of the questionnaire. These items were devoted to remote teaching and focused on the learners' perception of its difficulties, its organization and effectiveness and the instructors' assessment.

2.2. Research questions

This case study aimed at investigating the engineering students' attitudes to distance and blended learning and how they reacted to the innovation in teaching and learning methodologies in the context of an extreme scenario. The research questions (RQ) were:

(RQ1) What was the university students' evaluation of the effectiveness and organisation of the ERT and how were they influenced by predictors like students' gender, educational level of degree study, academic year of attendance (AYA), or experience gained in the Bologna process cycle attended by learners?

(RQ2) Did the university students' perception of difficulties change in the switch from in-presence educational strategy to online instruction? If this is the case, did the difficulties increase or decrease? How were these results influenced by the above predictors?

(RQ3) Did the university students' evaluation of their instructors change in the switch from in-presence educational strategy to online instruction and how was this response influenced by the predictors?

2.3. Participants

The research activity, which involved 3,183 engineering students, aged 19–25, was implemented at the end of the second term of the academic year 2020–2021. Responding to a specific item of the questionnaire, 1,057 participants self-reported as female (F), 2,126 as male (M) and nobody chose other alternatives. Moreover, considering their educational level of degree study, 2,227 learners were BS and the remainders 956 were MS. In Italy BS encompass learners enrolled between the first and third academic year (level 6 of the European Qualification Framework (EQF6)), while MS include fourth and fifth-year learners (level 7 of the European Qualification Framework (EQF7)). In this study, respondents were also grouped on the basis of their AYA: Table 1 shows these data and allows to derive further information.

2.4. Assessment tool

The engineering students' assessment of the online learning approach was investigated through a section of the overall questionnaire, consisting of 14 items (see Supplementary Materials). Participants'

Table 1. Number of engineering students involved in the research, grouped by all independent variables.

		Educational level of degree study		AYA				
		BS (EQF6)	MS (EQF7)	1 (EQF6)	2 (EQF6)	3 (EQF6)	4 (EQF7)	5 (EQF7)
Gender	M	1502	624	410	527	565	317	307
	F	725	332	202	270	253	205	127
TOT		2227	956	612	797	818	522	434

evaluation was expressed based on a five-point Likert scale, whereby a score equal to 3 corresponded to neutrality (neither negative nor positive, neither ineffective nor effective, neither worse nor better). This part of the survey was adapted from previous and already used questionnaire items (Chakraborty et al., 2021; Marzoli et al., 2021; Petillion & McNeil, 2020).

Taking into account these foregoing studies, we hypothesised that these items might refer to three independent factors: organisation and effectiveness of the online academic courses, modification of the university students' perception of difficulties in the passage from in-presence to online instruction, and academic learners' variation in the assessment of their instructors since the period preceding the COVID-19 pandemic. To check this hypothesis and test the construct validation, a confirmatory factor analysis was implemented. According to Kline (2016, pp. 274–275), the calculated value of both the Tucker-Lewis Index (Steiger, 1990) (TLI $= 0.928 > 0.90$) and the Root Mean Square Error of Approximation (Tucker & Lewis, 1973) (RMSEA $= 0.073 < 0.08$ reasonable approximate fit) confirmed it.

Afterwards, Cronbach's alpha statistics was used to estimate the internal consistency of the yielded unidimensional scales (Cortina, 1993; Cronbach, 1951; Field et al., 2013; Streiner, 2003; Taber, 2018). Notwithstanding the low number of items (particularly for scale 1), the reliability analysis reported in Table 2 supported the three-factor model (Field et al., 2013; Gardner, 1995; Green et al., 1977; Taber, 2018; Tavakol & Dennick, 2011).

The engineering students' opinion about each question was expressed based on a five-point Likert scale. As a measure of the learners' assessment regarding the three aforementioned factors, we considered the mean value of the Likert scores assigned to the questions referring to each specific factor. Figure 1 shows which items fall into each factor.

2.5. Data analysis

The data were preliminarily explored by descriptive statistics and then normality and homogeneity of variance were tested. An introductory investigation consisted in focusing our attention on the students'

Table 2. Summary of the reliability analysis for each subscale.

Factor	Items number	Cronbach's alpha	Strength of association	G6 (smc)	average_r
Organisation and effectiveness of the online academic courses	2	0.70	Good	0.54	0.54
Modification of the university students' perception of difficulties in the passage from in-presence to online instruction	6	0.85	Very good	0.84	0.49
Variation in the academic learners' assessment of their instructors in the passage from in-presence to online instruction	6	0.83	Very good	0.81	0.43

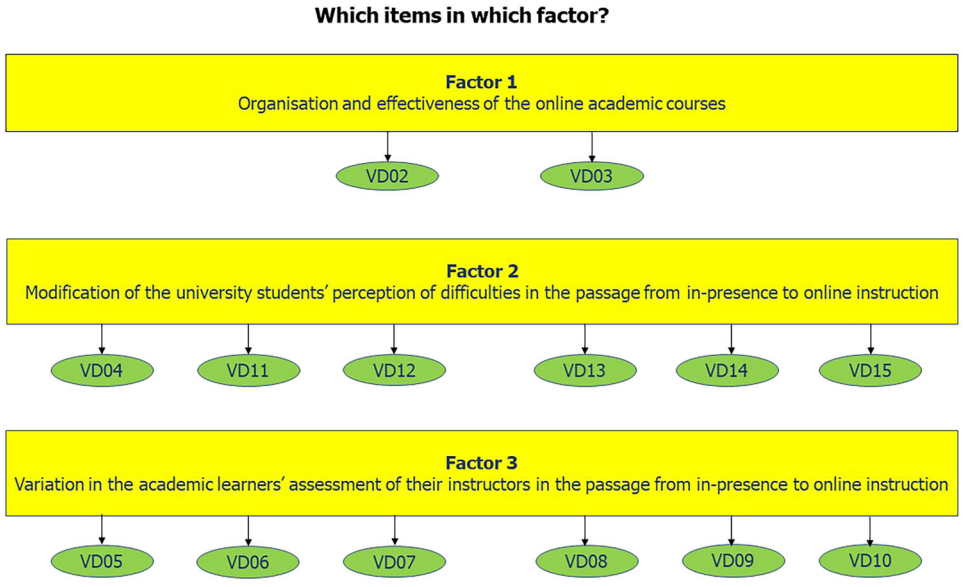

Figure 1. Factor structure. The ovals represent factors (unobserved constructs), while rectangles represent questionnaire items (observed variables).

opinions about their online learning experience through descriptive statistics. Moreover, the participants were arranged in different groups to inquire into the influence of the independent variables or predictors (i. e. gender, educational level of degree study, AYA, and experience gained in the Bologna process cycle) on these assessments.

On account of the large size of our sample, we always considered the population distributions normal pursuant to the central limit theorem. To investigate whether the variances in the cohorts were different, both Levene and Brown-Forsythe tests were carried out. Since the former could fail to control the Type I error rate if the population distribution was skewed, we prudently implemented also the latter test, which used deviations from the median or trimmed mean instead of deviation from the mean. Furthermore, the Brown-Forsythe test was less sensitive to the outliers than Levene, consequently we could better control the outliers' influence.

If they were both significant at p-value (p) inferior or equal to the target threshold, we could deduce that their null hypothesis was incorrect and argue that the assumption of homogeneity of variances had been violated. As a consequence, a two-way robust factorial ANOVA was implemented to analyse data. This robust test computed a trimmed mean which discarded 20% at both ends of the distribution, i.e. it excluded the lowest and the highest values, thus checking better the problem of possible outliers. However, when Levene and Brown-Forsythe were both not significant, the subsequent analysis was performed employing factorial ANOVA.

The statistical significance was preliminarily fixed at level $\alpha = 0.001$ instead of the conventional 0.05 on account of the large sample considered in this research. However, such a stringent threshold may penalise the statistical power of any test, i.e. its probability to correctly identify a genuine effect. As a consequence, a thoroughly evaluation of the results of the statistical tests was crucial, particularly when less numerous subgroups were involved and the p-values were higher than level α 0.001 instead of the conventionTaking into account the type of data collected, both Cohen-d (d) and a correlation effect size (r) were calculated to quantify the intensity of the effects and their values were classified coherently with Sawilowsky's rule of thumb (Sawilowsky, 2009). Data analysis was conducted by using the statistical open source software RStudio (https://www.rstudio.com/ accessed on 18 April 2024).

3. Results

In the following the results are grouped based on the research questions.

3.1. RQ1: effectiveness and organization of the online courses

To measure how the engineering students assessed the effectiveness and organisation of their online courses during the COVID-19 pandemic, a subscale was used consisting of two out of the global fourteen items (see supplementary material, VD02 and VD03). Table 3 summarises some outcomes classified on the basis of the distinct predictors investigated.

The mean and the median scores were considerably higher than 3 (neutral opinion), bar none. Table 4 shows some results regarding learners attending different academic years and aggregated by gender.

As the AYA increased, the mean scores and the medians tended to increase regardless of gender, with the exception of the fourth-year students, who achieved an even lower score than the third-year ones. To investigate the influence of gender and educational level of degree study as independent

Table 3. Descriptive statistics scores for different groups of students aggregated by predictors.

Group	Predictor	Students number	Median	Mean	Standard deviation
All students		3183	4.00	3.75	0.88
M	Gender	2126	4.00	3.75	0.91
F		1057	4.00	3.72	0.82
BS	Educational level of degree study	2227	4.00	3.71	0.88
MS		956	4.00	3.84	0.89
1st AYA (EQF6)	Academic year of attendance	612	3.50	3.54	0.80
2nd AYA (EQF6)		797	4.00	3.71	0.86
3rd AYA (EQF6)		818	4.00	3.83	0.93
4th AYA (EQF7)		522	4.00	3.74	0.89
5th AYA (EQF7)		434	4.00	3.96	0.88

Table 4. Descriptive statistics scores for learners attending different academic years, grouped by gender.

Group (gender-AYA)	Students number	Median	Mean	Standard deviation
M-1st	410	3.50	3.53	0.82
F-1st	202	3.50	3.56	0.77
M-2nd	527	4.00	3.71	0.87
F-2nd	270	4.00	3.72	0.83
M-3rd	565	4.00	3.84	0.96
F-3rd	253	4.00	3.80	0.85
M-4th	317	4.00	3.74	0.94
F-4th	205	4.00	3.75	0.82
M-5th	307	4.00	3.96	0.92
F-5th	127	4.00	3.96	0.78

Table 5. Post hoc test results and effect sizes calculated separately for female and male participants ($\alpha = 0.001$).

Contrast							
Group 1 (Bologna cycle)	Group 2 (Bologna cycle)	p-value	Statistical significance	d (M)	d (F)	r (M)	r (F)
1st AYA (1st)	2nd AYA (1st)	$0.00035 \ll 0.001$	Yes	−0.21	−0.20	−0.10	−0.10
1st AYA (1st)	3rd AYA (1st)	$0.00000 \ll 0.001$	Yes	−0.34	−0.30	−0.17	−0.15
1st AYA (1st)	4th AYA (2nd)	$0.00004 \ll 0.001$	Yes	−0.24	−0.24	−0.12	−0.12
1st AYA (1st)	5th AYA (2nd)	$0.00000 \ll 0.001$	Yes	−0.50	−0.53	−0.24	−0.25
2nd AYA (1st)	3rd AYA (1st)	$0.00823 \gg 0.001$	No	−0.14	−0.10	−0.07	−0.05
2nd AYA (1st)	4th AYA (2nd)	$0.40396 \gg 0.001$	No	−0.04	−0.04	−0.02	−0.02
2nd AYA (1st)	5th AYA (2nd)	$0.00002 \ll 0.001$	Yes	−0.29	−0.30	−0.14	−0.14
3rd AYA (1st)	4th AYA (2nd)	$0.10504 \gg 0.001$	No	0.10	0.06	0.05	0.03
3rd AYA (2nd)	5th AYA (2nd)	$0.03055 \gg 0.001$	No	−0.13	−0.19	−0.06	−0.09
4th AYA (2nd)	5th AYA (2nd)	$0.00060 \ll 0.001$	Yes	−0.24	−0.26	−0.12	−0.13

variables, we performed some techniques for statistical inference. Levene as well as Brown-Forsythe tests were not significant at level $\alpha = 0.001$ and data were consequently analysed by a factorial ANOVA. This test highlighted that there was a non-significant main effect of gender as well as a non-significant interaction effect between the two predictors on the students' mean score. Conversely, it emphasised a possible significant main effect of the type of degree programme attended. However, this latter result was not confirmed by post hoc comparisons and we argued that this independent variable did not have any influence on the learners' assessment. The intensity of the effect was calculated for completeness.

Furthermore, we considered the possible influence of the predictor AYA. Levene and Brown-Forsythe tests provided contrasting indications regarding homogeneity of variances: the former was negative, while the latter was positive even though not much higher than the established threshold equal to 0.001. To decide on a course of action, a prudent and conservative criterion was adopted; therefore, the hypothesis of homogeneity of variances was assumed to be not verified and inferential analysis was carried out through a two-way robust factorial ANOVA. This test revealed a significant main effect of the AYA on the learners' mean score ($p < 0.001$) and the post hoc test pointed out some statistically significant contrasts. Table 5 summarises the findings related to the post hoc test and the effect sizes, calculated separately for female and male participants. A negative effect size means that the mean score of group 1 was higher than the mean score of group 2 and vice-versa.

At level $\alpha = 0.001$, the post hoc comparisons involving freshmen were always statistically significant and the contrasts regarding second and fourth-year students, and third and fourth-year learners were undoubtedly non-significant. Differently, the contrasts involving second and third-year students, and third and fifth-year learners deserved attention. Considering the size of the samples and the effect size calculated, the statistical power corresponding to $\alpha = 0.001$ would be unacceptably low ($< 25\%$), while it would increase until more than 70% if $\alpha = 0.05$. As a result, we considered those two contrasts statistically significant.

The effect sizes regarding statistically significant contrasts were generally appreciable: d absolute value was between 0.10 (very small) and 0.53 (medium) and r ranged from 0.05 (very small) and 0.25 (medium). Furthermore, none of them was positive.

3.2. RQ2: change in university students' perception of difficulties

To measure the possible modification in engineering students' perception of difficulties in the passage from in-presence educational strategy to online instruction, a subscale was employed consisting of six

Table 6. Descriptive statistics scores for different groups of students aggregated by predictors.

Group	Predictor	Students number	Median	Mean	Standard deviation
All students		3183	2.67	2.74	0.78
M	Gender	2126	2.67	2.76	0.80
F		1057	2.67	2.68	0.74
BS	Educational level of degree study	2227	2.67	2.71	0.76
MS		956	2.83	2.79	0.83
1st AYA (EQF6)	Academic year of attendance	612	2.50	2.50	0.64
2nd AYA (EQF6)		797	2.67	2.72	0.75
3rd AYA (EQF6)		818	2.83	2.86	0.82
4th AYA (EQF7)		522	2.67	2.73	0.83
5th AYA (EQF7)		434	2.83	2.87	0.81

Table 7. Descriptive statistics scores for learners attending different academic years, grouped by gender.

Group (gender-AYA)	Students number	Median	Mean	Standard deviation
M-1st	410	2.50	2.50	0.66
F-1st	202	2.50	2.50	0.62
M-2nd	527	2.83	2.75	0.77
F-2nd	270	2.67	2.66	0.72
M-3rd	565	2.83	2.90	0.84
F-3rd	253	2.67	2.78	0.77
M-4th	317	2.67	2.78	0.86
F-4th	205	2.50	2.65	0.79
M-5th	307	2.83	2.88	0.82
F-5th	127	2.83	2.84	0.79

Table 8. Post hoc test results and effect sizes calculated separately for female and male respondents ($\alpha = 0.001$).

Contrast							
Group 1 (Bologna cycle)	Group 2 (Bologna cycle)	p-value	Statistical significance	d (M)	d (F)	r (M)	r (F)
1st AYA (1st)	2nd AYA (1st)	$0.00000 \ll 0.001$	Yes	−0.36	−0.24	−0.17	−0.12
1st AYA (1st)	3rd AYA (1st)	$0.00000 \ll 0.001$	Yes	−0.53	−0.40	−0.25	−0.19
1st AYA (1st)	4th AYA (2nd)	$0.00000 \ll 0.001$	Yes	−0.38	−0.22	−0.18	−0.11
1st AYA (1st)	5th AYA (2nd)	$0.00000 \ll 0.001$	Yes	−0.52	−0.51	−0.25	−0.24
2nd AYA (1st)	3rd AYA (1st)	$0.00000 \ll 0.001$	Yes	−0.18	−0.16	−0.09	−0.08
2nd AYA (1st)	4th AYA (2nd)	$0.31052 \gg 0.001$	No	−0.03	0.02	−0.02	0.01
2nd AYA (1st)	5th AYA (2nd)	$0.00167 > 0.001$	No	−0.16	−0.25	−0.08	−0.12
3rd AYA (1st)	4th AYA (2nd)	$0.00000 \ll 0.001$	Yes	0.14	0.16	0.07	0.08
3rd AYA (2nd)	5th AYA (2nd)	$0.48581 \gg 0.001$	No	0.03	−0.09	0.01	0.04
4th AYA (2nd)	5th AYA (2nd)	$0.00501 \gg 0.001$	No	−0.12	−0.25	−0.06	−0.12

out of the overall fourteen items (see supplementary material, VD04 and VD11-VD15). Table 6 shows some results classified on the basis of the different independent variables considered.

The mean and the median scores were considerably lower than 3 (neutral opinion), bar none. Table 7 shows some results regarding learners attending different academic years and aggregated by gender.

As the AYA increased, the mean scores and the medians tended to increase regardless of gender, with the exception of the fourth-year students, who achieved an even lower score than the third-year ones. To investigate the influence of gender and the educational level of degree study as predictors, we performed some techniques for statistical inference. Levene and Brown-Forsythe tests gave contrasting indications regarding homogeneity of variances: the former was negative, while the latter was positive. The two-way robust factorial ANOVA showed a non-significant (at .001) effect of both the independent variables on the students' mean score as well as a non-significant interaction effect between the two predictors.

Furthermore, we considered the possible influence of the independent variable AYA. The two-way robust factorial ANOVA revealed a significant main effect of the AYA on the learners' mean score ($p < 0.001$) and the post hoc test highlighted some statistically significant contrasts. Table 8 summarises the findings related to the post hoc test and the effect sizes, calculated separately for female and male respondents. A negative effect size means that the mean score of group 1 was higher than the mean score of group 2 and vice-versa.

At level $\alpha = 0.001$, the certainly significant contrasts were those between second and third-year learners, third and fourth-year students and all the contrasts involving freshmen. Differently, the contrasts

Table 9. Descriptive statistics scores for different groups of students aggregated by predictors.

Group	Predictor	Students number	Median	Mean	Standard deviation
All students		3183	2.83	2.85	0.74
M	Gender	2126	2.83	2.86	0.75
F		1057	2.83	2.83	0.70
BS	Educational level of degree study	2227	2.83	2.83	0.72
MS		956	2.83	2.90	0.77
1st AYA (EQF6)	Academic year of attendance	612	2.50	2.64	1.24
2nd AYA (EQF6)		797	2.83	2.83	0.71
3rd AYA (EQF6)		818	3.00	2.98	0.76
4th AYA (EQF7)		522	2.67	2.80	0.78
5th AYA (EQF7)		434	3.00	3.02	0.73

Table 10. Descriptive statistics scores for learners attending different academic years, grouped by gender.

Group (gender-AYA)	Students number	Median	Mean	Standard deviation
M-1st	410	2.67	2.64	0.63
F-1st	202	2.50	2.63	0.64
M-2nd	527	2.83	2.82	0.72
F-2nd	270	2.83	2.84	0.69
M-3rd	565	3.00	2.99	0.79
F-3rd	253	3.00	2.97	0.69
M-4th	317	2.83	2.84	0.81
F-4th	205	2.67	2.73	0.75
M-5th	307	3.00	3.01	0.75
F-5th	127	3.00	3.04	0.68

involving second and fifth-year students, and fourth and fifth-year learners deserved attention. Considering the size of the samples and the effect size calculated, the statistical power corresponding to $\alpha = 0.001$ would be unacceptably low ($< 55\%$), while it would increase up to more than 79% if $\alpha = 0.05$. As a result, we considered those two contrasts statistically significant.

The effect sizes regarding statistically significant contrasts were generally appreciable: d absolute value was between 0.12 (very small) and 0.53 (medium) and r ranged from 0.07 (very small) and 0.25 (medium). Furthermore, the only positive effect sizes were those characterising the contrast between third and fourth-year learners.

3.3. RQ3: change in university students' assessment of their instructors

To measure the possible modification in engineering students' assessment of their lecturers in the passage from in-presence educational strategy to online instruction, a subscale was employed consisting of six out of the overall fourteen items (see supplementary material, VD05-VD10). Table 9 shows some results classified on the basis of the different independent variables considered.

The mean and the median scores were generally lower than 3 (neutral opinion), with the exception of the third and fifth-year students, who achieved an outcome corresponding to neutrality. Table 10 shows some results regarding learners attending different academic years and aggregated by gender.

As the AYA increased, the mean scores and the medians tended to increase regardless of gender, with the exception of the fourth-year students, who achieved an even lower score than the third-year ones. We found a non-significant main effect of both gender and educational level of degree study (Factorial ANOVA, cut-off value .001, after normality assumptions were met) as well as a non-significant interaction effect between the two predictors on the students' mean score. The intensity of the effect was calculated for completeness.

Furthermore, we considered the possible influence of the independent variable AYA. We found a significant main effect of the AYA on the learners' mean score (robust two-way ANOVA, $p < 0.001$) and the post hoc test highlighted some statistically significant contrasts. Table 11 summarises the findings related to the post hoc test and the effect sizes, calculated separately for female and male participants. A negative effect size means that the mean score of group 1 was higher than the mean score of group 2 and vice-versa.

At level $\alpha = 0.001$, the non-significant contrasts involved only second and fourth-year students, and third and fifth-year learners. The effect sizes regarding statistically significant contrasts were generally

Table 11. Post hoc test results and effect sizes calculated separately for female and male participants.

Contrast							
Group 1 (Bologna cycle)	Group 2 (Bologna cycle)	p-value	Statistical significance	d (M)	d (F)	r (M)	r (F)
1st AYA (1st)	2nd AYA (1st)	0.00000 ≪ 0.001	Yes	−0.27	−0.31	−0.13	−0.15
1st AYA (1st)	3rd AYA (1st)	0.00000 ≪ 0.001	Yes	−0.48	−0.50	−0.23	−0.24
1st AYA (1st)	4th AYA (2nd)	0.00000 ≪ 0.001	Yes	−0.28	−0.14	−0.14	−0.07
1st AYA (1st)	5th AYA (2nd)	0.00000 ≪ 0.001	Yes	−0.54	−0.62	−0.26	−0.29
2nd AYA (1st)	3rd AYA (1st)	0.00000 ≪ 0.001	Yes	−0.22	−0.16	−0.11	−0.09
2nd AYA (1st)	4th AYA (2nd)	0.06344 ≫ 0.001	No	−0.02	0.16	−0.01	0.08
2nd AYA (1st)	5th AYA (2nd)	0.00000 ≪ 0.001	Yes	−0.26	−0.28	−0.12	−0.13
3rd AYA (1st)	4th AYA (2nd)	0.00000 ≪ 0.001	Yes	0.19	0.33	0.09	0.16
3rd AYA (2nd)	5th AYA (2nd)	0.14858 ≫ 0.001	No	−0.03	−0.11	−0.01	−0.05
4th AYA (2nd)	5th AYA (2nd)	0.00000 ≪ 0.001	Yes	−0.22	−0.43	−0.11	−0.21

appreciable: d absolute value was between 0.14 (very small) and 0.62 (medium) and r ranged from 0.07 (very small) and 0.29 (medium). Furthermore, the only positive effect sizes were those characterising the contrast between third and fourth-year learners.

4. Discussion

4.1. RQ1: effectiveness and organization of the online courses

The effectiveness and organization of the online courses were evaluated positively by the engineering students regardless of their gender and their being enrolled in a bachelor programme or in a master's programme. Conversely, AYA appeared to influence this evaluation without notable differences between F and M as well as BS and MS. Although all groups of students judged the online courses as effective and well organised, the freshmen's assessment was the lowest (mean value 3.54 out of 5, more than sufficient) while the fifth-year students' evaluation was the highest (mean value 3.96 out of 5, substantially good), without notable differences between female and male participants. In more details, the students' opinion on this issue became more and more positive with increasing years of attendance. This result was probably related to a greater autonomy and a deeper capacity to evaluate and interpret a very difficult situation which characterised more experienced learners.

The size of these differences was remarkable, as indicated by the effect sizes. In other words, their different mean scores indicated a real diverse evaluation of the effectiveness and organization of the online courses. To explain in a different way what it means that the effect sizes were generally appreciable, a common language effect size index could be used. According to McGraw and Wong (1992), in 64% of couples of learners consisting respectively of a student attending the first year and a student attending the fifth academic year, the latter will express a higher evaluation than the former.

Albeit faced with an extreme scenario, the educational innovation pursued through the adoption of technology to reinforce the instructors' activity does not appear to penalise the effectiveness of the academic courses as claimed by supporters of the traditional lectures. It is worth emphasising that an increasing use of technology seems to have the same impact on females and males, with no negative consequences on the already significant problem of the gender gap in Engineering faculties. However, the colder answer of freshmen than older students, probably related to the limited use of technological educational tools in Italian secondary schools, suggests that a gradual transformation of traditional academic courses into more modern ones might be appropriate across the first years of the degree programmes.

4.2. RQ2: change in university students' perception of difficulties

The university students' perception of difficulties appeared to change in the passage from in-presence educational strategy to the online instruction imposed by the COVID-19 pandemic. Findings suggest that it fairly increased (more difficulties perceived), regardless of learners' gender and their being enrolled in a bachelor programme or in a master's programme. AYA appeared to influence this evaluation, without notable differences between female and male respondents. Although all groups of

students claimed that the difficulties increased with distance learning (mean value 2.74 out of 5), the freshmen's assessment was markedly negative (quite far from 2.74 and from 2.79, i.e. the mean values of all other groups), as indicated also by the effect sizes which characterised the comparisons between these students and all the other learners' groups. From a different point of view and according to McGraw and Wong (1992), in 61% of couples of learners respectively of the first year and every other AYA the older students will express a lower negative evaluation than the younger ones.

In the context of both BS and MS, this perception of heightened difficulties tended to progressively decrease as the students' age and experience increased. Not only could we conclude that also the experience gained in the Bologna process specific cycle wherein the students were enrolled seemed to influence the learners' evaluation, but the impact of this independent variable prevailed even more so on the AYA effect. In this perspective, we could explain the fact that the fourth-year learners' assessment was equivalent to the judgment expressed by the second-year students and worse than the third-year ones.

Moreover, this predictor appeared to influence the learners' evaluation, and affected differently female and male participants. Considering the effect sizes which characterised respectively the comparison between women of the first and the fourth academic year ($d = -0.22$, $r = -0.11$) and men of the same years ($d = -0.38$, $r = -0.18$), it may be argued that the evaluation of the perceived difficulties by the two groups of women was lower than the evaluation expressed by men; indeed, this difference was 57% lower for women. This result appeared to confirm that the change in the educational pathway may be more critical for women.

As regards educational innovation, the learners' perception of difficulties appears to suggest that a radical change may be problematic if it is implemented in the first year of bachelor as well as masters' programmes. Moreover, a specific attention to females seems to be appropriate.

4.3. RQ3: change in university students' assessment of their instructors

The university students' assessment of their instructors appeared to change in the passage from in-presence educational strategy to the online instruction imposed by the COVID-19 pandemic. Findings indicated that it fairly decreased (worse assessment), regardless of learners' gender and their being enrolled in a bachelor programme or in a master's programme (mean value 2.85 out of 5).

Interestingly, AYA appeared to influence this evaluation; in the context of the same educational level of degree study, the students' assessment improved in a statistically significant way from the younger to the older learners. The teachers' educational approach and the relationship with learners were deemed by freshmen to be decidedly worse than they were before the pandemic (mean value 2.64 out of 5, far from 2.85 and from 2.91, i.e. the mean values of all other groups), while the second and fourth-year students' evaluation was less negatively connoted, although they expressed a worsening (mean value respectively 2.83 and 2.80 out of 5). Finally, both the third and fifth-year learners provided a neutral assessment (mean value respectively 2.98 and 3.02 out of 5).

Once again, the specific experience gained by every student in the particular academic degree programme significantly influenced the results and contributed to reinforcing the negative perception of the instructors, which characterised the respondents who had changed their level of the European Qualification Framework at the beginning of the academic year. Moreover, not only did this predictor appear to influence the learners' evaluation, but it could affect female and male students differently. Considering the effect sizes which characterised respectively the comparison between women of the first and fourth academic year ($d = -0.14$, $r = -0.07$) and men of the same years ($d = -0.28$, $r = -0.14$), it may be argued that the difference in the evaluation of instructors expressed by the two groups of women was lower than the evaluation expressed by men; indeed, this difference was half for women. This result seemed to further reinforce the conclusion that a change in the educational approach may be more critical for women.

4.4. Limitations

This study focused on engineering students' self-reported experiences of the ERT. Although it involved learners enrolled on both bachelor and master's programmes, the research did not investigate the

opinion of other important university actors, like instructors and doctoral candidates. Moreover, data were gathered through an online questionnaire to which the participant responded on a voluntary basis. Therefore, the sample involved was not random, even though it was massive, and the results cannot be generalised to the entire population of Italian engineering students.

5. Conclusions

As an undesirable effect of the sanitary crisis, the lock-down obliged universities to adopt ERT abruptly. However, for the Politecnico di Milano this turned out to be an opportunity to support its teachers' professional development across the entire academic year 2020–2021. As a consequence, the present study may provide a starting point for analysing the Politecnico di Milano engineering students' perception of such an effort, through a large survey.

The students' evaluation of the online learning experience highlighted, however, their opinion on three factors, which achieved a noticeably different assessment. The first one, i.e. the organisation and effectiveness of online academic courses, reached a substantially positive consensus. Nevertheless, the second one and the third one, namely the change in university students' perception of difficulties in the passage from in-presence to online instruction and their variation in the assessment of their instructors since the period preceding the COVID-19 pandemic, highlighted a deterioration in the student's opinion.

These results did not depend on the learners' gender or their educational level of degree study. The predictor AYA appeared to influence these outcomes regardless of student's gender; their opinions tended to progressively improve with their increasing age and academic experience. This effect, however, seemed to be countered by the change in the learning approach that learners experienced, for instance, when they achieved their bachelor degree at the end of their third academic year and started a masters' degree programme. This research highlighted that the fourth-year students' opinions were generally statistically equivalent to the judgments of the second-year learners. Moreover, this predictor might be more critical for female than male participants; women, indeed, seemed to suffer most from the transition between bachelor and master's programmes. Tutorship programmes and psychological services focused on women should be implemented to address this issue.

Due to the approach adopted in the present study, the results cannot be generalised to the entire population of Italian engineering students. Nevertheless, our findings yield some implications that policy makers and higher education institutions may take into account in online and blended learning programmes. Notwithstanding the students' positive opinion of the effectiveness and organisation of the academic courses during the COVID-19 pandemic, their overall evaluation was slightly negative. In the wider perspective of the university teaching innovation, one may argue that the availability and proper functioning of technological devices and instruments as well as the easy access to adequate technology and consistent Internet connection are undeniably necessary but not sufficient conditions to guarantee a positive learning experience or its improvement. In this regard, a crucial role may be played by teachers. Although our instructors knew how technological tools worked and proved to be able to use them effectively, they were not probably sufficiently conscious of how to exploit them in terms of pedagogical and educational efficacy. Accordingly, policy makers and higher education institutions ought to address this issue by designing and planning specific professional development programmes addressed to instructors, in order to implement online learning and teaching. Through this training they may renew traditional academic educational strategies. Our results, moreover, suggest that tutorship programmes and gender policies to support freshmen and women should be expanded and improved.

6. Implications for future studies

The present study is based on quantitative methods. Future investigations on ERT or more generally on online learning could adopt a mixed method approach, complementing quantitative and qualitative analysis. Online photovoice (Doyumğaç et al., 2020; Tanhan & Strack, 2020), Online Interpretative Phenomenological Analysis (Tanhan, 2020; Tanhan & Strack, 2020), Community-Based Participatory Research (Dari et al., 2023) or other approaches (Yang & Ghislandi, 2024) could offer rich insights into student experiences with online learning by integrating visual, experiential, and community-driven

perspectives. This approach would enhance understanding of diverse viewpoints and foster collaborative solutions for improving remote education.

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Disclosure statement

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Ethical approval

Approval for this study was obtained from Consulta dell Didattica (Meeting of July 13, 2021).

Informed consent statement

Informed consent was obtained from all participants involved in the study (first item of the questionnaire).

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Datasets are available on reasonable request to the authors. Supplementary Material makes available both the Italian and English version of the fourteen items.

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