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PAPER

The Contextual Environment as a Catalyst for Change in the Learning Process and Learning Styles of Students

Marina Sousa(✉), Jorge Mendonça, Eunice Fontão

ISEP, Polytechnic of Porto, Porto, Portugal

mas@isep.ipp.pt

ABSTRACT

This study aims to assess whether students' learning styles have changed due to the environmental context changes caused by the COVID-19 pandemic outbreak. This analysis is important because learning styles, in addition to predicting vocational outcomes, must inform the design of pedagogical practices and supports used in the teaching environment. To achieve this objective, a cross-sectional analysis was conducted on three cohorts of students who enrolled in an engineering course. Students in group 2 have been under confinement conditions during the previous year, while students in group 3 have been under confinement conditions for the previous two years. Group 1 consists of students who did not experience any confinement. The obtained results lead to the following conclusions: (i) The pandemic outbreak has led to environmental changes, pedagogical practices, and changes in the personality profiles of students, which can significantly impact the learning styles of students entering an engineering degree. (ii) While some learning styles are more susceptible to change, others remain resilient. (iii) The duration of exposure to the environmental changes caused by the pandemic outbreak has a greater impact on the changes in these learning styles.

KEYWORDS

contextual changes, learning styles, extended learning styles, teaching-learning process, secondary education, educational engineering

1 INTRODUCTION

Education systems at various levels have undergone significant changes due to the global calamity caused by the recent COVID-19 pandemic. Although education systems vary from country to country, the period corresponding to the pandemic has had and will continue to have a significant impact on education and future generations for many years [1].

In March 2020, the World Health Organization (WHO) declared a pandemic due to the widespread infection of people with the SARS-CoV-2 virus [2]. At the same

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time, the WHO aimed to halt the pandemic by establishing a set of health recommendations. These recommendations focused on maintaining body hygiene standards, wearing face masks, maintaining physical distance between individuals, and implementing restrictions on the shared use of public spaces.

In compliance with this normative standard, the governments of most countries have decided, either fully or partially, to suspend in-person activities in educational institutions at all levels during periods of high contagiousness. Since this incidence occurred in a variable manner over time, schools and universities were closed whenever the virus incidence was stronger and reopened when the pandemic "wave" became weaker. In Portugal, the focus of this study, there were three distinct periods of face-to-face activity closure: the first occurred between March and July 2020 the second between January and April 2021, and the third between January and February 2022 [3]. Although the WHO only declared the pandemic emergency condition extinct in May 2023, the widespread availability of medical solutions in the country has allowed for a drastic reduction in the incidence of the virus. As a result, the education system has been able to return to in-person classrooms since mid-2022.

The unexpected closure of school activities led to a transition from face-to-face teaching, with its long-standing pedagogical practices, to distance learning. This sudden change in teaching methods became known as "emergency remote teaching." Although there were already some ongoing projects, the majority of Portuguese schools did not consistently use pedagogical practices appropriate for the intensive use of digital technologies [4]. Thus, schools had to develop distance education plans under emergency conditions so that classes could continue in a non-present way. Teachers, students, and their families had to utilize their skills to support the teaching-learning process during this exceptional period [5].

In secondary education, students had to deal with teachers who, simplistically, transposed physical classes into online classes and others who, having more knowledge about digital education, implemented pedagogical practices more adapted to distance learning [4].

In this scenario, secondary school students, subject to the discipline of social confinement and to profound changes in the usual way of learning, were adapting, although the literature shows that they experienced, in general, changes in mental and behavioral health. More specifically, emotional reactions to COVID-19 showed stress, fear, fear of the unknown, worry, and restlessness [6, 7].

This study aims to evaluate the extent to which these environmental changes in the teaching-learning process, verified while attending the last years of secondary education, are reflected in the student's learning style, in the vocational predictor that modulates learning performance [8], and in a modeler of pedagogical practice of recognized importance [9, 10], particularly in the case of young people who enter and attend higher education, in this case, engineering courses. It also intends to contribute to helping define teaching-learning strategies for the post-COVID-19 period, sometimes called the "new normal," for engineering students [11].

2 LITERATURE REVIEW

Learning styles are the various ways in which each student retains and processes information during the learning process [12]. It is a classifier of the stimuli that best facilitate learning and the achievement of goals and programmatic objectives.

The receptiveness to these stimuli depends on individual characteristics that influence the way each student learns, such as cognitive abilities, gender, culture, and individual emotional intelligence [9].

Over time, various types of learning styles were designed, as well as assessment tools, which are essentially based on individual differences that influence the way people develop their learning development process [13]. This process has been widely studied in various scientific areas, giving rise to a wide range of theories and models that point to different ways of learning among individuals [14]. We highlight the models that point to the need to take into account the reciprocity between the modes of learning and the modes of teaching, which gives special emphasis to the identification of learning styles [15, 16]. This identification allows the teacher to know himself and his students better [17, 18], allowing him to design different classroom practices to improve performance.

Kolb and Kolb [19] argue that the learning styles of individuals are not constant, depend on genetic characteristics, lived experiences, and adaptability to the social environment, and may change, in certain circumstances, over time.

Koohestani and Baghcheghi [20] concluded in a four-year study conducted with students from the health sector that learning styles can change based on the environmental context, teaching methods employed, and the discipline in which students are enrolled. This finding allows the authors to conclude that students' learning styles are flexible and can be changed.

Similar results were obtained by Gurpinar et al. [21] in a study developed with medical students for one year, with the difference that they concluded that it was not the various teaching methods used that affected the learning styles but the environment in which they were inserted. However, the authors argue that the study time may not have been sufficient to verify changes related to teaching methods. Additionally, they found that not all learning styles were affected, which may mean that some styles are more resilient than others.

Bitran et al. [22] followed the evolution of the learning styles of medical students throughout a complete course and concluded that these were evolving from an abstract-reflective style to an abstract-active style. This change, according to the authors, may mean that students are adapting to the teaching model that, in the early years, is teacher-centered, and in the final years, is based on project-based learning (PBL).

Similarly, when pedagogical practice is based on active techniques, specifically utilizing the principles of constructivist pedagogy, it is possible to observe changes in learning styles over time [19, 23]. However, Van der Nerg [23] reports that not all learning styles can be changed. This suggests that certain styles may be more resistant to change compared to others.

It should be noted that, in the opposite direction, other studies did not find evidence, based on measurements made over time, that students' learning styles changed [24, 25]. These results can mean that the learning style of each student is an intrinsic characteristic of his personality and cannot undergo significant changes.

Thus, since there is no consensus among the various studies, it is necessary to continue studying the effect of learning styles under specific circumstances. This includes examining changes in the environmental context, pedagogical practices, and even personality changes.

The educational landscape has undergone significant changes worldwide due to the COVID-19 pandemic. In Portugal, during the pandemic, secondary education faced the need to change its usual pedagogical practices. It transitioned on a large scale from face-to-face education to remote education owing to an emergency mediated by digital technologies [4]. This change implied the need for teachers and students to quickly and significantly modify their working methods [5].

The widespread adoption of digital technologies during the pandemic has transformed traditional teaching tools, requiring teachers and students to rapidly acquire scientific, pedagogical, and technological knowledge [4]. This transition may have been simpler for secondary school students, who, being digital natives, found less difficulty adapting to the new environment of the teaching-learning process [26].

Even in an emergency, the changes to pedagogical practice were evident. For instance, teachers started creating digital content like educational videos and designing small tasks for students to complete in a digital setting. One of the motivations for the creation of educational videos was the fear that students would have greater difficulty learning without face-to-face classes [27].

Another significant change was the incorporation of smartphones or tablets into the learning-teaching process. This change was made in response to the need to integrate the digital environment and to accommodate the new generation's continuous use of these devices [4, 28]. These instruments allowed for the incorporation of mobile games in the educational process, among other practices. This practice has been shown to increase students' motivation for learning and improve learning outcomes [29].

All over the world, asynchronous and synchronous digital approaches have been introduced, along with the use of new platforms and tools, such as online questionnaires, for evaluating student performance [27]. Most of these platforms allow collaborative learning and content co-creation, which many authors argue allow students to reach higher levels in the acquisition of knowledge and contribute to the creation of new learning habits [30, 31]. Students have to develop their responsibility and autonomy skills in a scenario that offers flexibility in terms of time and place. They should also progress at their own pace [32, 33]. Although many teachers have established online schedules to provide support to parents and assist in the educational journey of students [27].

It should be noted that the economic situation of families was an additional difficulty for those with lower incomes or from less developed interior regions, with poorly developed network connections, and/or without adequate or outdated equipment. These families and their students had greater difficulties and experienced the educational process differently during the pandemic crisis [4, 5].

These profound changes had an impact on the student's personality profile. Personality can be defined as a symbolic characteristic that relates to the potential for activity in each individual. It presents itself as a brand image that differentiates individuals based on how they react to emerging events [1]. Several studies indicate that the COVID-19 pandemic has had a significant impact, albeit temporary, on the personality profile, well-being, and educational performance of secondary school students. This impact is attributed to cognitive decrease observed during the period of confinement [6, 34, 35]. Hammerstein [36] indicates that cognitive regression is primarily caused by social isolation resulting from the emergence of social confinement. This isolation significantly affects the risks of anxiety and depression, even after individuals have become accustomed to the environmental changes in their lifestyle.

This cognitive regression affects the emotions of students (and people in general) and decreases well-being, sleep disorders, generalized anxiety disorders, and depression or post-traumatic stress [37, 38]. These psychiatric conditions are considered very serious for adolescents due to the far-reaching impact of mental illness on physical health, which extends into adulthood [39]. These effects were more strongly felt by younger and lower socio-economic students [36]. Even after the resumption of face-to-face teaching, the symptoms of academic anxiety were still evident in the behavior of students. This can be attributed to the continued implementation of preventive practices, such as the use of masks and social distancing [40].

In conclusion, there is evidence of the impact of the school closures due to the COVID-19 pandemic on both pedagogical practices and the personality profiles of students.

Although there have already been a considerable number of studies on the impact of COVID-19 on young people's learning, the subject is still too recent to be considered part of the established knowledge of Kunh. This study aims to contribute to the understanding of this topic. Furthermore, this impact will continue over the next few years, so it is necessary to continue studying it. In particular, the study of this contextual impact change on the learning styles of students who, as we have seen, can be influenced by the described changes induced by the pandemic.

More specifically, this study aims to answer the following questions concerning secondary school students in Portugal at the time of their entry into an engineering higher education school:

- Q1: Does the context associated with the COVID-19 pandemic contribute to or significantly change in the learning styles of students beginning higher engineering studies?
- Q2: Does the context associated with the COVID-19 pandemic contribute to or determine whether certain learning styles of students starting higher engineering studies are more resilient to change than others?
- Q3: Does the duration of confinement periods during secondary education affect the learning styles of students who begin higher engineering studies?

3 MATERIALS AND METHODS

3.1 Instrument: K-LSI

There are several instruments available in the literature for evaluating learning styles. One of the most successfully used instruments in engineering education is the Kolb learning styles inventory (K-LSI), developed by Kolb [41–43] to assess how individuals perceive and process information. The measurement instrument used in this study was the K-LSI, version 3.1. This version consists of a 12-item rating method using a forced choice that enables the identification of students' learning modes. In each of the 12 items, four statements are presented, which are scored from 4 (indicating the best learning) to 1 (indicating the worst learning). The result is four scores: concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE) [19]. These scores are then combined to determine the values of AC-CE (preference for abstraction over realization) and AE-RO (preference for action over reflection). This instrument is reliable and valid [19, 44, 45].

3.2 Data analysis

This study was conducted at the Engineering School of Porto Polytechnic in September 2020, 2021, and 2022, with students for the academic years 2020/2021 (Year 1), 2021/2022 (Year 2), and 2022/2023 (Year 3). The students are attending the Electrical and Computer Engineering course, and all of them are enrolled in their first year.

Data collection was conducted using an online platform, Google Forms, during classes, with the assistance of the teachers. The objectives of the study were explained in detail to the students, and voluntary participation was ensured. The nature of the questionnaire and the proper way to answer it were also explained, using illustrative images.

The response rate, considering only correctly completed questionnaires, was 88.4% for Year 1, 92.3% for Year 2, and 82.7% for Year 3.

The data collected from the online platform was entered into an Excel database and transferred to an SPSS version 28 database. Statistical analyses were performed using SPSS, including tests of proportions, Student's t-test, factor analysis, and Pearson's correlation.

3.3 Sample

Table 1 displays the gender distribution and percentage of students in the three years of the study.

Table 1. The demographic composition of the sample, in percentage

	Gender		Total
	Female	Male	
Year 1	8 (5.4%)	139 (94.6%)	147
Year 2	22 (10.8%)	181 (89.2%)	203
Year 3	13 (7.7%)	156 (92.3%)	169
Total	43 (8.3%)	476 (91.7%)	519

The average age of the individuals in the sample is 20, with a mean of 18 (276 respondents) and only 60 respondents over 25. As can be seen in Table 1, almost 92% are male. The sample is essentially composed of young men. This sample corresponds to the traditional profile of first-year engineering students.

4 RESULTS

The internal validity of the K-LSI instrument was analyzed using scale intercorrelations and factor analysis for the three years under study. Tables 2, 3, and 4 display the results of a reliability analysis for Cronbach's alpha coefficients, which assess the internal consistency of the KLSI scales. Additionally, the tables present an analysis of the intercorrelations between the scales using Pearson product-moment correlations. Tables 5, 6, and 7 show the results of the principal component analysis. Varimax rotation was used to extract the 2 factors using the 4 primary LSI scales.

Table 2. Coefficient alpha reliability and scale intercorrelations for year 1 (*alphas displayed in brackets*)

	CE	RO	AC	AE	AC-CE	AE-RO
CE	(0.623)					
RO	–0.276**	(0.695)				
AC	–0.394**	–0.252**	(0.697)			
AE	–0.235**	–0.496**	–0.333**	(0.734)		
AC-CE	–0.824**	0.004	0.846**	–0.070	–	
AE-RO	0.021	–0.863**	–0.050	0.867**	–0.043	–

Notes: *significant at the level 0.05; **significant at the level 0.01.

Table 3. Coefficient alpha reliability and scale intercorrelations for year 2 (*alphas displayed in brackets*)

	CE	RO	AC	AE	AC-CE	AE-RO
CE	(0.661)					
RO	–0.220**	(0.686)				
AC	–0.414**	–0.210**	(0.733)			
AE	–0.233**	–0.496**	–0.345**	(0.761)		
AC-CE	–0.829**	–0.003	0.852**	–0.078	–	
AE-RO	–0.019	–0.852**	–0.091	0.877**	–0.045	–

Notes: *significant at the level 0.05; **significant at the level 0.01.

Table 4. Coefficient alpha reliability and scale intercorrelations for year 3 (*alphas displayed in brackets*)

	CE	RO	AC	AE	AC-CE	AE-RO
CE	(0.699)					
RO	–0.187*	(0.701)				
AC	–0.407**	–0.175*	(0.720)			
AE	–0.216**	–0.476**	–0.296**	(0.737)		
AC-CE	–0.841**	0.008	0.837**	–0.046	–	
AE-RO	–0.024	–0.850**	–0.078	0.868**	–0.032	–

Notes: *significant at the level 0.05; **significant at the level 0.01.

Cronbach's alpha was used to assess the internal consistency, reliability of the survey instrument, and the respective values are shown in Tables 2, 3, and 4. The alpha value ranged between 0.623 and 0.737, indicating moderate internal consistency among the survey items. According to Barbera et al. [46], these values are considered acceptable. This suggests that the survey instrument is a reliable measure of the construct being studied.

In assessing the scale intercorrelations, six variables were considered: those measuring the four learning process orientations: CE, RO, AC, and AE, and the two combinations measuring the preference for abstractness over concreteness (AC-CE) and action over reflection (AE-RO).

Because CE, RO, AC, and AE are ipsative in nature, negative correlations are expected. However, the combined variables AC-CE and AE-RO are not ipsative, so the prediction is that AC-CE and AE-RO should not be correlated, which is the case for all three years under study. Similarly, we found that CE and AC do not correlate with AE-RO and that AE and RO are not correlated with AC-CE in the three years under study. The correlation between CE, RO, AC, and AE is not significant due to the negative correlations induced by the method.

Table 5. Factor analyses of the scales for Year 1

	Two Factor Solution	
	Factor 1	**Factor 2**
CE	0.006	0.793
AC	0.040	–0.872
RO	0.855	0.041
AE	–0.874	0.076
Variance (%)	38.146	34.186
Cumulative (%)	38.146	72.332
Eigen Value	1.526	1.367
Varimax rotation with Kaiser normalization		

Table 6. Factor analyses of the scales for Year 2

	Two Factor Solution	
	Factor 1	**Factor 2**
CE	0.075	0.807
AC	0.107	–0.871
RO	0.818	0.046
AE	–0.904	0.076
Variance (%)	38.433	34.598
Cumulative (%)	38.433	73.031
Eigen Value	1.537	1.384
Varimax rotation with Kaiser normalization		

Table 7. Factor analyses of the scales for Year 3

	Two Factor Solution	
	Factor 1	**Factor 2**
CE	0.078	0.822
AC	0.103	–0.855
RO	0.816	0.026
AE	–0.895	0.050
Variance (%)	37.660	34.656
Cumulative (%)	37.660	72.316
Eigen Value	1.506	1.386
Varimax rotation with Kaiser normalization		

The results of the factor analysis using the principal components method and varimax rotation support a two-component solution, which accounts for 72.3% of the total variance in Year 1, 73.0% in Year 2, and 72.3% in Year 3. The results are in line with the prediction that factorial analysis leads to two bipolar factors, one with AC and CE as poles and the other with AE and RO as poles. The study of the internal characteristics of measurement instruments constructed with ipsative data, such as the LSI, has some limitations and can lead to factor analyses that are complex to examine. However, it remains the most appropriate method for identifying the instrument's internal validity [42, 45].

Table 8 presents the results of the minimum, maximum, and mean scores across the years under study. For all years, the domain with the highest mean score was AE, while the lowest was concrete experience.

Table 8. Mean scores and standard deviations (SD)

		Minimum	Maximum	Mean	SD
CE	Year 1	15	40	25.87	5.87
	Year 2	16	42	26.30	5.72
	Year 3	16	44	25.47	5.26
AC	Year 1	17	47	31.48	5.92
	Year 2	15	48	31.50	6.11
	Year 3	16	44	30.89	5.65
RO	Year 1	15	43	28.80	6.04
	Year 2	14	44	28.31	5.99
	Year 3	16	45	28.05	5.97
AE	Year 1	17	48	33.97	6.45
	Year 2	17	45	34.13	6.52
	Year 3	19	47	35.64	6.04
AC-CE	Year 1	–22	28	5.61	10.05
	Year 2	–23	27	5.20	9.94
	Year 3	–20	26	5.42	9.15
AE-RO	Year 1	–26	27	5.18	10.84
	Year 2	–24	27	5.82	10.83
	Year 3	–19	25	7.60	10.43

To determine the impact of the changes, the difference between the variables (AC-CE and AE-RO) was calculated, and the absolute value of the changes was used in the analysis (Table 9). Year 1 students predominantly prefer abstraction over concretion (AC-CE) and a lower preference for action over reflection (AE-RO). However, Year 2 and 3 students reverse the previous results. The change has more impact for Year 3 students, with a considerable change compared to the other variations.

Table 9. Differences between AC-CE and AE-RO in three years

	AC-CE		AE-RO	
	Year 2	Year 3	Year 2	Year 3
Year 1	0.41	0.19	0.64	2.42

To determine if the observed differences are statistically significant, a student's t-test for independent samples was conducted, and the findings are presented in Table 10. The tests show that only the difference between AE-RO from Year 1 to Year 3 is statistically significant.

Table 10. Tests t student for AC-CE and AE-RO (*p-value displayed in brackets*)

	AC-CE		AE-RO	
	Year 2	Year 3	Year 2	Year 3
Year 1	0.379 (0.705)	0.177 (0.860)	–0.546 (0.585)	–2.015 (0.045*)
Year 2		–0.220 (0.413)	–1.610 (0.108)	

Notes: *significant at the level 0.05; **significant at the level 0.01.

The graphical representation of these four variables (CE, AC, RO, and AE) through partial sums of their values leads to the identification of a point in each quadrant that qualifies the learning style of each respondent (accommodating, converging, diverging, and assimilating) [19].

The learning style types—accommodating, converging, diverging, and assimilating—are determined by dividing the AC-CE and AE-RO scores at the fiftieth percentile of the total norm group and graphing them on the LSI-Grid. The cut point for the AC-CE scale is +7, and the cut point for the AE-RO scale is +6 [19]. The results of these conditions are shown in Table 11.

Table 11. Cut-points for learning style types

Learning Styles	AC-CE	AE-RO
Accommodating	<=7	>=7
Converging	>=8	>=7
Diverging	<=7	<=6
Assimilating	>=8	<=6

The application of the described conditions leads to the determination of learning styles values for each of the years under study (Table 12).

Table 12. Mean scores for the styles over three years

		Accommodating	Converging	Diverging	Assimilating	Total
Year 1	n (%)	38 (25.8)	50 (34.0)	27 (18.4)	32 (21.8)	147 (100)
Year 2	n (%)	58 (28.6)	57 (28.1)	41 (20.2)	47 (23.1)	203 (100)
Year 3	n (%)	61 (36.1)	34 (20.1)	37 (21.9)	37 (21.9)	169 (100)
Total	N (%)	157 (30.2)	141 (27.3)	105 (20.2)	116 (22.3)	519 (100)

As indicated in Table 10, in Year 1, the predominant learning style is converging, while the other styles show similar values, except for the diverging style, which has a lower value. In Year 2, there is a change with a decrease in the percentage of the converging style and an increase in the other styles. The percentage of accommodators and convergents is practically the same. Finally, in Year 3, the predominant style becomes accommodating, and there is a decrease in the percentage of the other styles compared to Years 1 and 2.

To determine if the observed differences are statistically significant, independent sample tests of proportions were conducted. The results of these tests are shown in Table 13. According to the test results, we discovered that the accommodating style had a significantly lower impact in Year 1 compared to Year 3. The converging style presented a significantly greater impact in Years 1 and 2 compared to Year 3.

Table 13. Tests of differences of proportions for the styles in three years (*p-value in brackets*)

	Accommodating	Converging	Diverging	Assimilating
Year 1 – Year 2	0.563 (0.573)	51.189 (0.234)	–0.427 (0.669)	–0.306 (0.760)
Year 1 – Year 3	–1.958 (0.025*$)	2.789 (0.004**)	–0.778 (0.437)	–0.027 (0.979)
Year 2 – Year 3	–1.549 (0.121)	1.778 (0.038*$)	–0.400 (0.689)	0.289 (0.772)

Notes: *significant at the level 0.05; **significant at the level 0.01; $ unilateral.

This classification of learning styles can be further refined by incorporating the six core variables: CE, AC, RO, AE, AC-CE, and AE-RO. The objective is to better define individual learning styles as well as reduce the difficulty of interpreting boundary values in the classification of the four styles [47, 48]. The new learning styles are acting, analyzing, balancing, deciding, experiencing, imagining, initiating, reflecting, and thinking. Instead of dividing the grid at the 50th percentiles for AC-CE and AE-RO, the new styles are defined by dividing the two normative distributions into thirds [49]. Concrete regions are defined by < 6, abstract regions by > 14, active regions by > 11, and reflective regions by < 1. Table 14 shows the cut-points of the extended learning styles [49].

Table 14. Cut-points for extended learning styles

Learning styles	AC-CE	AE-RO
Acting	]5, 15[	>11
Analyzing	> 14	< 1
Balancing	]5, 15[	]0, 12[
Deciding	> 14	> 11
Experiencing	< 6	]0, 12[
Imagining	< 6	< 1
Initiating	< 6	> 11
Reflecting	]5, 15[	< 1
Thinking	> 14	]0, 12[

The application of the described conditions results in the determination of extended learning styles values for each of the years being studied. As can be seen from Table 15, all nine learning style were identified in the sample. In Year 1, the predominant learning styles are experiencing, initiating, and imagining. The other styles have similar values, except for the deciding style, which has a lower value. In Year 2, the predominant styles are experiencing, initiating, and imaging. However, there is an increase in the importance of style acting and a decrease in the significance of style analyzing and thinking. Lastly, in Year 3, it appears that the predominant imaging style is no longer present and has been replaced by the initiating style. Additionally, the trend of decreasing analysis and thinking styles continues. It should be noted that in the years under study, the least represented style is the deciding style, and its values are low.

Table 15. Mean scores for the extended styles over three years

		Year 1	Year 2	Year 3
Acting	n (%)	15 (10.2)	28 (13.8)	18 (10.7)
Analyzing	n (%)	12 (8.2)	13 (6.4)	9 (5.3)
Balancing	n (%)	14 (9.5)	22 (10.8)	28 (16.6)
Deciding	n (%)	7 (4.8)	9 (4.4)	8 (4.7)
Experiencing	n (%)	23 (15.6)	38 (18.7)	29 (17.2)
Imagining	n (%)	28 (19.0)	31 (15.3)	17 (10.1)
Initiating	n (%)	24 (16.3)	31 (15.3)	37 (21.9)
Reflecting	n (%)	10 (6.8)	16 (7.9)	12 (7.1)
Thinking	n (%)	14 (9.5)	15 (7.4)	11 (6.5)
Total	N (%)	147 (100)	203 (100)	169 (100)

To determine if the observed differences are statistically significant, independent sample tests of proportions were conducted. The results of these tests are presented in Table 16. According to the test results, it was found that the balancing style in Year 1 had a significantly lower impact compared to Year 3. The imaging style presented in Year 1 had a significantly greater impact than in Year 3.

Table 16. Tests of differences of proportions for the extended styles in three years (*p-value in brackets*)

	Year 1 – Year 2	Year 1 – Year 3	Year 2 – Year 3
Acting	–1.032 (0.302)	–0.130 (0.897)	0.927 (0.354)
Analyzing	0.620 (0.535)	0.998 (0.318)	0.443 (0.658)
Balancing	–0.403 (0.687)	–1.880 (0.030*$)	–1.593 (0.111)
Deciding	0.144 (0.885)	0.012 (0.495)	–0.138 (0.890)
Experiencing	–0.757 (0.449)	–0.363 (0.717)	0.391 (0.696)
Imagining	0.920 (0.358)	2.258 (0.024*)	1.522 (0.128)
Initiating	0.267 (0.790)	–1.264 (0.206)	–1.631 (0.103)
Reflecting	–0.384 (0.701)	–0.104 (0.917)	0.286 (0.775)
Thinking	0.703 (0.482)	0.480 (0.327)	0.333 (0.739)

Notes: *significant at the level 0.05; $unilateral.

5 DISCUSSION AND CONCLUSIONS

The objective of the study was to examine the perception of a potential shift in learning styles resulting from the environmental changes brought about by the COVID-19 pandemic in the teaching and learning process. The study utilized Kolb students enrolled in an engineering course.

The methodology used focuses on a cross-sectional analysis of students from the management discipline of an engineering course. The analysis was conducted over three consecutive years, starting from the year they entered university after finishing secondary school, all within a pandemic context. Year 1 students were not affected by the pandemic outbreak during their secondary school years, and to some extent, they can be seen as a control group. Year 2 students had one year of contact with the pandemic outbreak, and the students in group 3 had two years of contact with the outbreak. The students in groups 2 and 3 were thus affected by the contextual changes discussed in the literature review.

To facilitate the discussion of the results, Figures 1, 2, and 3 provide improved visualization and monitoring of the results presented in the previous tables.

Figure 1 shows the evolution of the components AC-CE and AE-RO in the years of the study. The first of these components, AC-CE, indicates a student's preference for abstraction over embodiment as the most effective method of learning. The second component, AE-RO, indicates a preference for action over reflection.

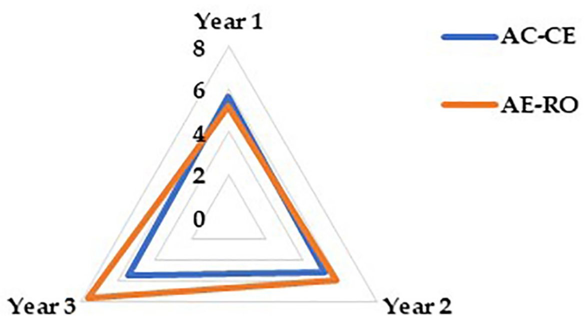

Fig. 1. Differences between AC-CE and AE-RO over the course of three years

In Year 1, students in the control group demonstrate a relatively balanced preference between abstraction/realization and action/reflection. But as the influence of environmental change continues, students accentuate their preference for action from year 1 to year 3. Here, too, the transition seems to be gradual and strengthened with duration under the influence of contextual changes.

Regarding learning styles, the results shown in Figure 2 indicate that the dominant learning style for the year 1 group is converging, followed by accommodating and assimilating learning styles. Students with diverging learning styles are in the minority in the sample. These results are consistent with those reported by Kolb [19, 48] and Bajpai et al. [50], which suggest that students with a dominant convergent learning style tend to have a higher aptitude for engineering disciplines, while students with a dominant accommodating learning style tend to excel in management. This is consistent with the notion that Group 1 can be regarded as acontrol group.

However, when the results are observed sequentially for Years 2 and 3, it was found that there is a clear and statistically significant change in the positions of converging and accommodating styles, indicating a shift in their predominance. It appears to be a chronological progression, as in the second year, Year 2, these two styles emerge with a relatively equal and intermediate position. Diverging and assimilating styles do not appear to undergo significant changes.

Thus, it seems possible that, under the influence of environmental changes induced by the pandemic outbreak, engineering students under analysis, whose dominant learning style was characterized by active experimentation and abstract conceptualization, may shift their learning preference towards methodologies that are based on concrete experience and active observation of phenomena. Students with converging and accommodating learning styles generally have extroverted personalities. However, while convergers prefer to think about problem-solving, accommodators prefer to build solutions, especially through emotions. Accommodators rely more on intuition than logic, tend to rely on other people's information rather than their own analysis, and are attracted to new challenges and experiences [51].

Conversely, students with diverging and assimilating learning styles are generally introverted; the first is predominantly sensory, while the second is intuitive. These styles, which are a minority in the sample, proved to be more resilient to change.

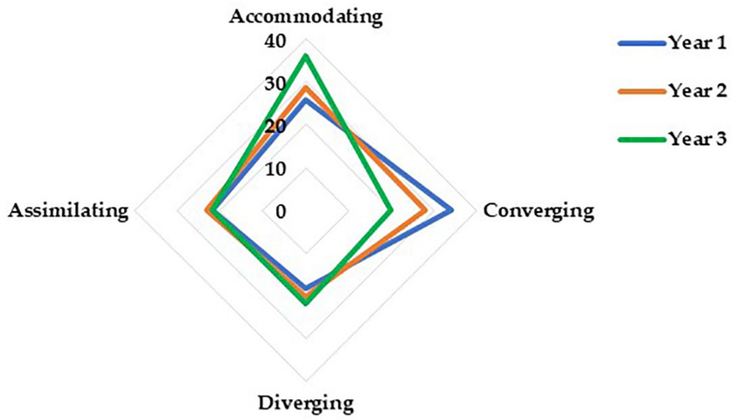

Fig. 2. Distribution of learning styles over the course of three years

Figure 3 analyzes the same reality using expanded styles, which offer us a more detailed but simultaneously more complex view. These learning styles allow for a more comprehensive understanding of the dialectical tensions in the learning process, specifically the dialectics between CE and AC, as well as AE and RO.

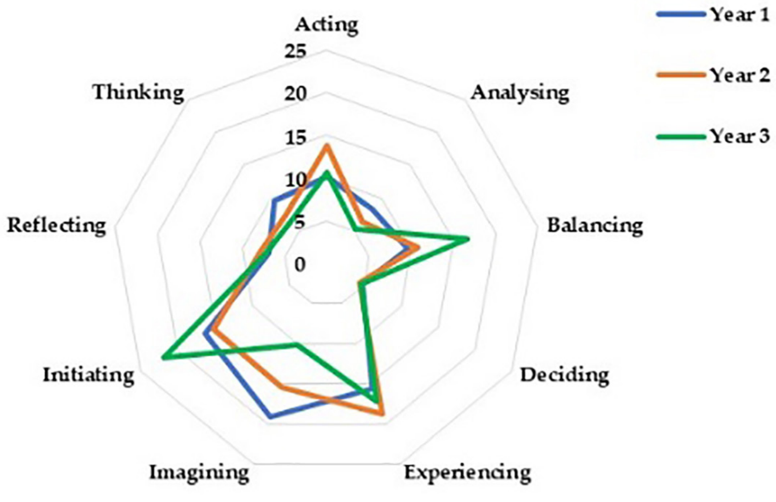

Fig. 3. The distribution of extended learning styles over the course of three years

This diagram shows that in Year 1, the predominant style is imagining. As expected, there has been a noticeable change in learning styles over time. In Year 3, the dominant styles are initiating and experiencing, with the former being more prevalent.

The imagining style presupposes the predominance of CE and RO components. However, in Year 3, these components regress, with the components of initiating, balancing, and experiencing styles becoming predominant in value. The initiating style still presupposes the predominance of the CE component, but the RO and AE components undergo a qualitative change, shifting from predominantly RO to predominantly AE. The experiencing style maintains a predominant value of CE, presenting relatively balanced values between LA and RO. The balancing style has similar values in its four components: CE, AE, RO, and AC. In this style, similar to the imagining style, there are significant differences between Years 1 and 3.

Students whose predominant learning style is imagining learn well in groups because group work allows them to generate ideas and receive information from their peers. Students whose predominant learning style is initiating learn well in groups because group work enables them to accomplish tasks, set goals, and explore various approaches to completing a project. This distinction is one of the primary modifications that must be taken into account. In both situations, students prefer teachers who possess tutor and facilitator characteristics. Students with a balanced learning style learn best when they are exposed to a variety of pedagogical practices, such as lectures, group work, debate sessions, or laboratory classes. In turn, students with a sense of style not only work well in groups but also benefit from individual consolidation of learning and require constructive feedback to evolve [52, 53].

The obtained results enable us to compile the answers to the formulated research questions. The context associated with the COVID-19 pandemic has contributed to and influenced significant changes in the learning styles of students enrolling in an engineering course. Additionally, the change in these students was more significant for the learning styles converging and accommodating, or for the expanded learning styles classifier in the balancing and imagining styles. Assimilating and diverging styles, as well as expanded analyzing, reflecting, and experiencing styles were relatively resilient to the influence of contextual changes. Finally, the time of exposure to contextual changes influenced, in a progressively increasing way, the modification in learning styles that changed.

These changes observed in this study can be explained by shifts in pedagogical practices, specifically the integration of technology to support the teaching-learning process, transitioning from face-to-face to online formats. The study focused on secondary school students in the second largest city in the country who did not experience significant technological difficulties in accessing online resources, except for those that may be attributed to the varying economic backgrounds of their families [4]. They can also be explained by the impact of school closures on the personality profiles of students [40]. However, it is crucial to continue observing learning styles in the coming years to determine whether these changes are enduring or if they were merely a special result of a unique situation.

In conclusion, the results of this study indicate that changes in context, such as modifications in teaching practices or alterations in personality profiles, can result in changes in students' learning styles. This finding leads to the validation of the theory developed by Kolb [41]: that learning styles are flexible characteristics and not innate and unalterable characteristics of the student. Teachers who are aware of their students' preferred learning styles can tailor their pedagogical practices accordingly [44, 54]. The obtained results are important for teachers to adapt their main pedagogical practices used in the teaching-learning process with students in the so-called "new normal" in a compatible manner.

Limitations and future research: This empirical study has several limitations. The first relates to the method of data collection, which is a self-report survey. This technique is widely used in social science research, but there is a possibility that respondents may not fully understand the questions being asked and may have a tendency to overvalue their performance. The fact that surveys were answered in the classroom in the presence of a teacher can help mitigate this issue. One solution would be to conduct tests and retest reliability, but with shorter intervals to ensure that the results are not external conditions. The second limitation is related to the sample size. The study was constructed at a single engineering school, which restricts the generalizability of the findings. Finally, the choice of the instrument to evaluate learning styles, which, like all instruments developed based on a theoretical framework and/or model, has critiques regarding its validity [55]. Further research in this area should be conducted in the coming years to compare the findings and conclusions of this study. It would be highly intriguing to replicate this study in various engineering schools and countries to validate the observed shift in learning styles among engineering students.

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7 AUTHORS

Marina Sousa is a Professor at the Department of Organisation and Management at the School of Engineering of Polytechnic of Porto, Portugal. She specializes in Strategic Management of Universities at the Polytechnic University of Catalunya. She has a Master's degree in Social and Legal Sciences, specialization in Economics, Business and Labour and a PhD in Economic and Business Sciences from the University of Extremadura. She was Vice-President and member of the Board of Management of the Polytechnic of Porto. She was Chief Executive Officer of the Polytechnic of Porto Foundation. Her area of interest include Globalization, Internationalization, European Integration, Strategic Management, Governance of Higher Education and Engineering Education (E-mail: mas@isep.ipp.pt).

Jorge Mendonça is a Professor at the Department of Mathematics at the School of Engineering of Polytechnic of Porto, Portugal. He holds a PhD degree in Statistics and Operational Research from the University of Vigo, a Master's degree in Statistics and Probability from the Faculty of Sciences of the University of Lisbon. He holds a Degree in Educational Mathematics from the Faculty of Sciences of the University of Porto. He was co-coordinator of the Erasmus project-DRIVE-MATH – Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees. His main research areas are Engineering Education and Statistics (Survival analysis, Survey analysis) (E-mail: jpm@isep.ipp.pt).

Eunice Fontão is a Professor at the Department of Civil Engineering at the School of Engineering of Polytechnic of Porto, Portugal. She graduated in Civil Engineering from Faculty of Engineering of the University of Porto and completed a Master in Environmental Engineering and a PhD in Civil Engineering in the same University. She began her career in construction business. She was member of the School of Engineering of Polytechnic Representatives Council is at the present a member of the Technical and Scientific Council. Her interest lies in Energy Efficiency Urban Planning and Engineering Education (E-mail: emf@isep.ipp.pt).