

Influential academic factors in the integration of ICT in higher education after the COVID-19 pandemic

Álvaro Antón-Sancho¹, Pablo Fernández-Arias¹, Georgios Lampropoulos^{2,3}, Diego Vergara^{1,*}

¹ Technology, Instruction and Design in Engineering and Education Research Group (TiDEE.rg), Catholic University of Ávila, 05005 Ávila, Spain

² Department of Applied Informatics, University of Macedonia, 54636 Thessaloniki, Greece

³ University of Nicosia, 1700 Nicosia, Cyprus

* **Corresponding author:** Diego Vergara, diego.vergara@ucavila.es

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Abstract: The emergence of the COVID-19 pandemic led to the need to move educational processes to virtual environments and increase the use of digital tools for different teaching uses. This led to a change in the habits of using information and communication technologies (ICT), especially in higher education. This work analyzes the impact of the COVID-19 pandemic on the frequency of use of different ICT tools in a sample of 950 Latin American university professors while focusing on the area of knowledge of the participating professors. To this end, a validated questionnaire has been used, the responses of which have been statistically analyzed. As a result, it has been proven that participants give high ratings to ICT but show insufficient digital competences for its use. The use of ICT tools has increased in all areas after the pandemic but in a diverse way. Differences have been identified in the areas of knowledge regarding the use of ICT for different uses before the pandemic. In this sense, the results suggest that Humanities professors are the ones who least use ICT for didactic purposes. On the other hand, after the pandemic, the use of ICT for communication purposes has been homogenized among the different knowledge areas.

Keywords: digital learning environments; information and communication technologies; COVID-19 pandemic; academic factors; digital competences; digital skills; assessment

1. Introduction

The unprecedented conditions that emerged due to the COVID-19 pandemic have several implications in the educational domain and significantly affected educational stakeholders (Ramos-Pla et al., 2022; Salame et al., 2023). The use of information and communication technologies (ICT) tools was imperative to continue providing education during the pandemic as they allow for ubiquitous learning, educational material distribution, and interactive communication (Hu and Li, 2017; Simonson and Schlosser, 2009; Wallace, 2003). Not only students, but teachers as well had to familiarize themselves with using ICT in their classrooms (Turst and Whalen, 2020). Moreover, the degree of acceptance and the professors' assessment of the use of ICTs positively influences the degree of acceptance of ICTs by students (Bouziane et al., 2023). As a result, besides the several challenges that had to be addressed, the cultivation of digital skills and familiarization with integrating ICT in teaching and learning activities arose as some of the main benefits (Bond, 2020; Ferri et al., 2020; Lampropoulos and Admiraal, 2023). This is particularly true in higher education in which faculty has demonstrated increased digital skills during and after the pandemic (Antón-Sancho and Sánchez-Calvo, 2022; Esteve-Mon et al., 2020; Jorge-Vázquez et

al., 2021) which, in turn, has led to an increase in the adoption of ICT in higher education in the post COVID-19 period (Alharbi et al., 2022; Liesa-Orús et al., 2020; Saif et al., 2022; Sormunen et al., 2021).

In the Latin American region, which is the specific focus of this study, there are two main limitations to the process of digital integration of universities. On the one hand, the technological obsolescence of equipment and inequalities in terms of access to and use of digital technologies or the Internet (Cifuentes and Herrera-Velásquez, 2019). On the other hand, the scarce digital training of university professors (Basilotta-Gómez-Pablos et al., 2022; Pathirana and Karunaratne, 2023). This last aspect acts as a persistent brake on the digitization process in higher education because it hinders its use even when the university has the appropriate technologies (Basilotta-Gómez-Pablos et al., 2022). The analysis of the adoption of ICTs by university students and professors in the region is an interesting line of research because it can provide universities with keys to assist in the process of digitalization of higher education. For this reason, in recent years instruments have been developed to measure the use and valuation of ICT by the agents involved in university education (Vargas-Merino et al., 2022; Vergara et al., 2023b).

The specialized literature reveals that the digital competence of Latin American university professors is, in general, insufficient (Cabero-Almenara et al., 2021). There are studies focused on a specific area of knowledge that corroborate the insufficient digital competence of university professors and, in addition, find academic factors that condition this digital competence. For example, professors at private universities express a digital competence more than 7% higher than professors at public universities in fields such as Engineering (Vergara et al., 2022) or arts education (Antón-Sancho et al., 2024). It follows that the greater investment made by private universities in technology and faculty training significantly increases digital literacy. Other studies have shown that male professors express digital skills about 3% higher than female professors (Vergara et al., 2023b). This shows that there are also sociological factors, such as gender, that influence the digital skills expressed by professors.

On the other hand, there are divergences in the preceding literature as to how the professors' area of knowledge influences perceived digital competence. For example, the digital competence expressed by Engineering professors (Vergara et al., 2022) is almost 32% higher than that expressed by a collective of university professors from all subject areas, within the same region (Vergara et al., 2023b). Despite this, there are no studies in the literature that systematically study how the area of knowledge influences the self-perception of digital competence. This paper aims to fill this gap in the literature, which is interesting for helping universities to plan the training of their teaching staff more effectively in terms of digital competence.

Regarding ICT use habits, although the increase of its use is obvious, there are various factors that can influence the way and to what degree they are being integrated in higher education. Recent studies have examined factors related to professors such as their digital generation, attitude, age, experience, digital literacy, socio-economic background, and gender (Antón-Sancho, Vergara, et al., 2023; Antón-Sancho, Fernández-Arias, et al., 2023; Gómez-Poyato et al., 2022; Jorge-Vázquez et al., 2021; Núñez-Canal et al., 2022; Antón-Sancho, Vergara et al., 2023). More specifically, in

their study Antón-Sancho, Vergara, et al. (2023) focused on examining the role of digital generation in adopting and using ICT tools. Their findings revealed that both digital natives' and digital immigrants' digital skills were improved, but the digital competences of digital natives were increased to a higher extent than those of digital immigrants. The improved perception of teaching competence is associated with a greater increase in the use of ICT by digital natives. Specifically, digital natives increased their use of ICTs by 8% to 20% more than digital immigrants after the pandemic (Antón-Sancho, Vergara et al., 2023).

In a follow-up study, Antón-Sancho, Fernández-Arias, et al. (2023) explored how the experience and age of professors influenced their perspectives regarding ICT tools and the frequency of using them in their classrooms. Based on the results, professors' age and experience affected their use of ICT tools. In addition, an age-based digital gap that existed prior to the pandemic was bridged with digital skills of most professors being improved. However, a gender gap favoring female professors was observed in terms of digital skills and ICT tools use. The influence of professors' gender on their use of different types of ICT tools was examined in a recent study conducted by Vergara et al. (2023a). Their study showed that self-concept of digital skills affected male professors more in comparison to female professors when it comes to their ICT assessment. In addition, female professors had a larger increase of ICT use when compared to male professors which could create a gender-gap in the future. Previous studies (Jorge-Vázquez et al., 2021; Núñez-Canal et al., 2022) also analyzed the role of professors' digital skills prior to the pandemic and how their ability to effectively use ICT tools was influenced during the pandemic. Their findings revealed that professors' digital competences were related to their ability to offer high quality lessons in online environments as well as to students' learning. Additionally, professors that had prior knowledge and skills in digital technologies and online learning environments adjusted to the requirements of emergency remote teaching more easily.

The results of these studies have showed that different factors can affect ICT use in higher education to a different degree. This fact becomes more evident when taking professors' unique traits into account. The identification of these influencing factors is of key importance because it allows universities to adapt their digital inclusion and faculty training policies to the specific needs of different groups. Many of the recent studies evaluate ICT tools as a whole and not based on specific categories or use cases. Additionally, perspectives from professors in Latin America Universities are not being widely examined. To the best of our knowledge, there has been no study that thoroughly examines how professors' area of knowledge affects their integrating ICT in their classrooms.

To address this gap in the literature, this study aims to explore to what extent academic factors, such as knowledge area, influence professors' use of ICT tools in higher education. Specifically, professors in Latin America whose area of knowledge falls in the Humanities, Sciences, Health Sciences, Social Sciences, or Engineering are examined. This classification is in line with UNESCO's taxonomy of knowledge areas (UNESCO, 2012). Emphasis is put on their assessment of the didactic use of ICT in higher education as well as their self-concept of digital competence. In addition, the classification and categorization of ICT tools into communication, interaction,

sharing, and evaluation tools suggested by Garrote-Jurado et al. (2014) are followed to achieve a better understanding on how each type of ICT tool is being influenced. Specifically, communication tools refer to digital channels that allow the transmission of oral or written information between professor and students or among students, such as Teams[®] or Meet[®]. Interaction tools consist of platforms that enable joint and group tasks to be carried out, such as Moodle[®] or Blackboard[®]. Sharing tools, such as Youtube[®] or TikTok[®], allow professors to share teaching materials of a digital nature with their students, beyond the traditional paper-based materials. Finally, evaluation tools allow new forms of assessment of acquired knowledge and skills, as in the case of Kahoot[®].

Thus, the general objective of this research is to test whether the area of knowledge of Latin American university professors significantly influences their adoption of different ICT tools during the COVID-19 pandemic. Specifically, the aim is to achieve the following research questions:

RQ1: How does the area of knowledge of professors influence their assessment the self-concept of digital competence and their training in the use of digital technologies? This question seeks to find gaps by area of knowledge in the evaluations expressed by the participants of their digital competence and the training they have in terms of digital training.

RQ2: How does the pandemic affected the use of ICT among university professors depending on the specific family of tools according to their teaching use? This question aims to measure the frequency of use of the different ICT tools between participating professors before and after the pandemic and compare both frequencies of use, to find, if there are any, significant differences.

RQ3: How does the area of knowledge of professors influence the increases in the use of ICT after the pandemic according to the area of knowledge of the participants? The aim is to compare the increases identified in the frequencies of ICT use by teachers from different areas of knowledge in search of significant differences.

2. Materials and methods

2.1. Participants

The target population is practicing university professors in the Latin American and Caribbean region. The criteria for inclusion in the study were the following: (i) to be a university professor, in any area of knowledge, in a Latin American university; and (ii) to have registered and attended a training session on the didactic use of ICT in higher education given by the authors. Therefore, the sampling process was non-probabilistic by convenience. The training session took the form of a 2-hour master class with the following objectives: (i) to present the basic concepts of ICT and their use as teaching resources in higher education; (ii) to classify ICT tools according to the teaching uses they can have (interaction, communication, sharing, and evaluation); and (iii) to present examples of the application of ICT tools in different areas of knowledge and teaching uses. Participation in the training session allowed to assume that the participants had, at the time of their participation in the study, a sufficient and homogeneous knowledge of the relevant concepts about ICT and its classification according to teaching uses. After the training session, the participants received the

questionnaire used as a research instrument, which they answered having been informed in writing of the research purposes of their answers. Participation was free, voluntary and anonymous, and no data that could lead to the identification of the participants was collected at any time during the research process. The research process was approved by the Research Ethics Committee of the University of Guadalajara, with code CEI/93/2023. Finally, of the 1289 participants registered in the training course, 950 professors responded to the questionnaire, and all the answers received were valid (in the sense of being complete).

2.2. Research variables

In this study, the area of knowledge of the participants was considered as an explanatory variable. This is a polytomous nominal variable. Its possible values are the five major areas of knowledge considered in the International Standard Classification of Education (ISCED), of the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2012), including the area of education within the area of Social Sciences. specifically, the areas considered are the following: (i) Arts and Humanities (hereafter, Humanities); (ii) Pure, Experimental, and Natural Sciences (hereafter, Sciences); (iii) Health Sciences; (iv) Social and Legal Sciences (hereafter, Social Sciences; and (v) Engineering, Architecture and Technical Learning (hereafter, Engineering).

Six explanatory variables are also distinguished. The first two are the participants' self-concept of digital competence and their assessment of the didactic use of ICT in higher education. Both are quantitative and have been measured on Likert scales from 1 to 5, where 1 corresponds to a very low rating and 5 to a very high rating. The other four variables measure the expressed frequency of use of each of the 4 types of ICT tools considered in the study (communication, interaction, sharing, and evaluation), both before and after the pandemic. These frequencies have been measured on a new Likert scale from 1 to 5, where 1 means very low frequency and 5 means very high frequency.

2.3. Research instrument

A standardized and validated questionnaire was used in this research (Vergara et al., 2023b). This questionnaire consists of 11 questions classified into three parts. The first part consists of 4 questions that request an assessment of their digital skills in terms of technical, pedagogical, communicative, and ethical aspects, respectively. The second part consists of 3 questions, which ask for an assessment of the didactic use of ICT in higher education in terms of improvement in academic performance, motivation, and inclusiveness. Finally, the third part consists of 4 questions that ask to assess the frequency of use, both before and after the pandemic, of each of the four families of ICT tools: communication, interaction, sharing, and evaluation. All the ratings requested are measured on Likert scales from 1 to 5, where 1 corresponds to the lowest rating and 5 to the highest.

This instrument has been validated in terms of its construct by means of an exploratory factor analysis that identifies the families of questions described as factors (Vergara et al., 2023b). The factor weights vary between 0.74 and 0.84 for the first

factor identified and between 0.67 and 0.82 for the second. In addition, it has also been validated in terms of its internal reliability, through the computation of the Cronbach alphas and composite reliability parameters, which are all above 0.80 (Vergara et al., 2023b).

2.4. Statistical analysis

Quantitative research was carried out based on the answers given by the participants to the questionnaire used as a research instrument. For the validation of the responses obtained, the statistics of the confirmatory factor analysis, which confirms the theoretical model of the original instrument, and the Cronbach’s alpha and composite reliability parameters were computed. For the analysis of the responses on digital competence and ICT assessment, the main descriptive statistics were computed. Since normality tests were negative, we chose to use the Kruskal-Wallis nonparametric test to identify significant differences by areas of knowledge among the ratings expressed. The Kruskal-Wallis test was also used to contrast whether there are significant differences in the frequencies of use among the different families of ICT tools considered. All hypothesis testing was carried out with a significance level of 0.05.

3. Results

3.1. Distribution of participants

A total of 950 Latin American university professors participated in the study (500 males and 450 females), distributed according to areas of knowledge as shown in **Table 1**. There is a significant majority of professors of Social Sciences and Engineering, followed by professors of Sciences and Health Sciences, with the Humanities being the minority represented. The distribution of participants by knowledge areas, therefore, is not homogeneous (chi-square = 143.51, $p < 0.05$).

Table 1. Distribution of participants by area of knowledge.

Area of knowledge	Number of participants	Proportion (%)	Males	Females
Humanities	158	16.63	75	83
Sciences	145	15.26	80	65
Health Sciences	96	10.11	56	40
Social Sciences	295	31.05	143	152
Engineering	256	26.95	146	110

3.2. Instrument validity

The theoretical model given by the exploratory factor analysis (Vergara et al., 2023b) of two families of questions is consistent with the statistics of the confirmatory factor analysis computed with the answers obtained in this research. The incremental fit indices are good (adjusted GIF = 0.92145; CFI = 0.9407; IFI = 0.9418; NFI = 0.9173; TLI = 0.9037). The absolute fit indices are also good (AIC = 473.78; GFI = 0.9821; SRMR = 0.0888). The internal consistency of the responses is also ensured, given that both Cronbach’s alpha and composite reliability parameters are all greater

than 0.70 (**Table 2**).

Table 2. Cronbach alphas and composite reliability parameters of the responses.

Family of questions	Cronbach alpha	Composite reliability
Digital competence	0.8207	0.8139
ICT assessment	0.7940	0.7921

3.3. Digital competence and ICT assessment

The participants value the didactic usefulness of ICTs higher than their digital competence for their use (**Table 3**). Specifically, the evaluation of ICT is high (above 4 out of 5), while the evaluation of digital competence itself is intermediate (between 3 and 4 out of 5). Moreover, the ratings of ICT are more homogeneous than the ratings of digital competence (**Table 3**), so it can be assumed that there is a certain uniformity in the ratings of ICT that does not exist in the self-concepts of digital competence, which are more heterogeneous.

Table 3. Descriptive statistics of the different families of responses.

Family of questions	Mean (out of 5)	Standard deviation (out of 5)	Coefficient of variation (%)
Self-assessment of digital competence of professors (Vergara et al., 2023b)	3.68	0.86	23.44
Assessment of didactic usefulness of ICT tools (Vergara et al., 2023b)	4.21	0.76	18.09

The normality tests computed on the different families of responses were negative, so the Kruskal-Wallis nonparametric test was chosen to decide on the significance of the differences among the mean responses differentiated by subject area (**Table 4**). No significant differences were identified in the ratings of ICT among professors of different knowledge areas. However, there are significant differences in the self-concept of digital competence. Specifically, Health Sciences professors express a lower digital competence, at an average level, than the rest of the professors, with Engineering professors expressing the highest digital competence (**Table 4**).

Table 4. Average responses, differentiating by knowledge area, and statistics of the Kruskal-Wallis test.

Area of knowledge	Digital competence	ICT assessment
Humanities	3.66	4.15
Sciences	3.70	4.26
Health Sciences	3.30	4.30
Social Sciences	3.69	4.19
Engineering	3.81	4.22
KW chi-square	111.05	5.17
<i>p</i> -value	<0.05	0.27

3.4. Use of ICT tools before and after the pandemic

At a general overall level, the bilateral Wilcoxon test identifies significant growth

in the frequencies of ICT use after the pandemic, both in the communication ($W = 188440, p < 0.05$), interaction ($W = 198166, p < 0.05$), sharing ($W = 286101, p < 0.05$), and evaluation ($W = 202494, p < 0.05$) tools. The growth rates, illustrated through the slopes of the lines in **Figure 1**, are similar for the communication, interaction, and evaluation tools. In contrast, the lowest growth rate, which corresponds to the lowest slope, is in the sharing tools, which are the most frequently used before the pandemic (**Figure 1**).

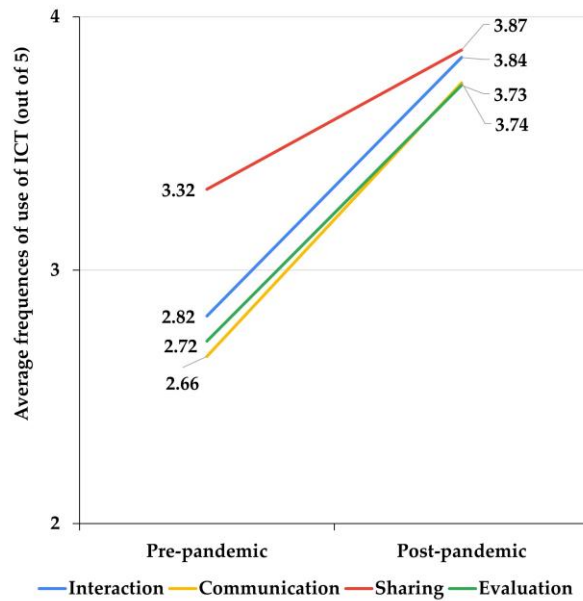


Figure 1. Growth in the frequencies of use (over 5) of the different families of ICT tools among participants.

The Kruskal-Wallis test shows that, before the pandemic, there would be significant differences, distinguishing by knowledge areas, in the frequencies of use of the four considered families of ICT tools: interaction (chi-square = 16.88, $p < 0.001$), communication (chi-square = 12.22, $p = 0.02$), sharing (chi-square = 26.30, $p < 0.001$), and evaluation (chi-square = 30.65, $p < 0.001$). Specifically, Sciences and Engineering professors were the most frequent users of all types of ICT tools before the pandemic (Appendix, **Tables A1** and **A2**). Professors who used ICT tools the least are Health Sciences professors (Appendix, **Table A3**), except for communication tools, which were used the least by Humanities professors (Appendix, **Table A4**). However, after the pandemic, no significant differences are identified in the frequency of use of communication ICT by subject area (chi-square = 8.04, $p = 0.09$), although differences by subject area persist in the frequencies of use of ICT for interaction (chi-square = 23.59, $p < 0.001$), sharing (chi-square = 13.11, $p = 0.01$), and evaluation (chi-square = 12.49, $p = 0.01$).

Regarding the rates of increase, in all areas of knowledge, the tools whose use grows the least after the pandemic are those of sharing (Appendix). However, significant divergences are observed in terms of the tools whose use grows the most (Appendix). Specifically, in Humanities and Sciences, the use of interaction tools increased the most, followed by communication tools (Appendix, **Tables A1** and **A4**). On the other hand, in Health Sciences the tools whose use is growing the most are

those for evaluation (Appendix, **Table A3**) and in Social Sciences those for communication (Appendix, **Table A5**). In Engineering, the use of evaluation tools is growing the most, followed closely by communication tools (Appendix, **Table A2**).

4. Discussion

This study focused on comprehending how professors in Latin America area of knowledge affected their use of different types of ICT tools prior and after the COVID-19 pandemic while also exploring their ICT assessment and digital competences by analyzing data from the two periods. A total of 950 professors from universities in Latin America took part in this study by fully completing their respective questionnaire. Based on the findings, the area of knowledge of most participants was Social Sciences (31.05%) followed closely by Engineering (26.95%). Perspectives of participants whose area of knowledge was Humanities (16.63%) and Sciences (15.26%) were also examined. Finally, Health Sciences (10.11%) was the area of knowledge with the lowest number of participating professors. Therefore, it can be inferred that the distribution based on area of knowledge was not homogeneous.

When taking into account professors' responses to their self-concept of digital skills and ICT assessment, it can be inferred that professors highly regarded the use of ICT as an educational tool. However, professors reported an intermediate self-concept of digital competences. This fact highlights the need to provide adequate training programs for educational stakeholders to further reap the benefits that the adoption and integration of ICT can yield in education. Moreover, when considering professors' area of knowledge, some additional findings arose. Specifically, professors whose area of knowledge was Engineering had the highest self-concept of digital competences (average 3.81) followed by those in Sciences (average 3.70). Intermediate results also emerged from professors whose area of knowledge was Social Sciences (average 3.69) and Humanities (average 3.66). Professors whose knowledge area was Health Sciences had the lowest self-concept of digital competences (average 3.30). According to the results, significant differences were observed in the self-concept of digital competences when taking into consideration professors' area of knowledge. Thus, RQ1 is answered affirmatively in relation to the self-concept of digital competence.

However, no significant differences were observed in professors' ICT assessment as professors of all areas of knowledge, that is Health Sciences (average 4.30), Sciences (average 4.26), Engineering (average 4.22), Social Sciences (average 4.19), and Humanities (average 4.15), had a positive and similar perspective regarding the potentials of ICT to be used as an effective educational means. Therefore, RQ1 has a negative response regarding the assessment of the training received in digital training. Therefore, professors state that their digital training is insufficient, and they do so uniformly. But, on the other hand, they show differences in terms of their digital competence, from which it follows that, in part, the origin of their digital competence is not the training received as professors, but, probably, what they have based on the training they received when they were students.

The findings above are in line with and further expand those of other related studies (Antón-Sancho, Fernández-Arias, et al., 2023; Jorge-Vázquez et al., 2021). Specifically, the digital skills of professors in scientific-technical areas reported by

Antón-Sancho, Fernández-Arias et al. (2023) are slightly lower than those found here for professors in the same areas. This may indicate the existence of underlying sociological variables that influence the perceptions expressed, so that changing the sample and the time at which the data are collected may alter the results. However, the most important original contribution of this work is to find that there are significant differences between the perceptions expressed by professors from scientific-technical areas with respect to professors from other areas.

On the other hand, it is worth noting that the digital competence expressed here by humanities professors is 32% lower than that expressed by professors in the arts area (Antón-Sancho et al., 2024), with arts education included in humanities education. This may be because Antón-Sancho et al. (2024) is focused on the specific use of virtual reality technologies, which may condition the assessments expressed. Something similar occurs among Engineering professors, who here express digital skills 38% below what was reported by Vergara et al. (2022), also focused on the use of virtual reality.

Regarding the use of different types of ICT tools, an increase in the frequency of use was observed in all types of tools after the pandemic. This answers RQ2. This fact is in line with the results of other related studies (Antón-Sancho, Vergara, et al., 2023; Antón-Sancho and Sánchez-Calvo, 2022) which highlighted that as professors' digital skills improved so did their use of ICT tools. Specifically, although an increase in communication, interaction, sharing, and evaluation tools was noticed, sharing tools had the lowest growth rate. This fact can be justified by the wide use of ICT tools to share material and resources even prior to the pandemic.

Furthermore, significant differences were observed regarding the use of different types of ICT tools prior to the pandemic based on professors' knowledge area. Professors whose area of knowledge was Sciences or Engineering were the ones who most frequently used all different types of ICT tools whereas Humanities professors were the ones that used communication tools the least and Health Science professors were the ones who used interaction, sharing, and evaluation tools the least. Nonetheless, it is worth noting that no significant differences were observed regarding the use of ICT tools by professors with different areas of knowledge. Besides sharing tools having the lowest growth due to their popularity prior to the pandemic, the growth of interaction tools and communication tools was most obvious in professors of Humanities and Sciences while communication tools showed the most increase in use by Social Sciences professors. Moreover, evaluation tools had the largest increase in use by Health Sciences and Engineering professors. This answers RQ3. These results highlight the general increase in digital skills, use of ICT for educational purposes, and familiarization with integrating ICT in classrooms caused by the unprecedented conditions that professors among other educational stakeholders had to overcome and the effort they had to put to cultivate their digital literacy skills on their own.

These findings further expand upon and validate those of the existing literature which have found differences among the areas of knowledge of professors in terms of frequency in using ICT tools as well as those that highlighted the role of ICT tools as an effective educational means (Antón-Sancho and Sánchez-Calvo, 2022). Specifically, Antón-Sancho and Sánchez-Calvo (2022) verified that the pandemic

caused a general increase in the use of ICT, but here it has been shown, as an original contribution, that this increase has led to a more homogeneous use of the different ICT tools.

5. Conclusion

The participating professors expressed having an intermediate digital competence (below 4 out of 5), but a very high evaluation of the educational use of ICT in higher education (above 4 out of 5). There are no significant differences among areas of knowledge in the evaluation of ICT. However, as a novel contribution of this research it has been found that there are significant differences in the self-concept of digital competence. Specifically, Engineering professors are those who express greater digital competence and Health Science professors are those who express less digital competence. In fact, there is a difference of 15.45% between them. Professors of Sciences, Humanities, and Social Sciences express an intermediate level of digital competence, between those of Engineering and Health Sciences professors, without significant differences between the first three.

Before the COVID-19 pandemic, the ICT tools most used by the participants were content sharing tools, between 18.57% and 24.81% more than the rest of the tools. After the pandemic, homogeneity has been achieved in terms of the frequency of use of the different ICT tools. The use of ICT tools for sharing materials has grown the least after the pandemic, with an increase of 16.57% in the frequency of its use. The rest of the ICT tools, for interaction, communication, and evaluation, grew, respectively, by 36.17%, 37.13%, and 40.60%. By areas of knowledge, before the pandemic, Science and Engineering professors were the ones who used all types of tools the most. However, Humanities professors are the ones who use ICT for teaching purposes the least, which implies the need to reinforce the digital training of professors in these areas. After the pandemic, the gap by subject area in the frequency of use of ICT for communication has been corrected, although the gaps by subject area persist in the use of the rest of the tools.

From this study, it is derived, consequently, that the response given by university professors in the Latin American region to unforeseen situations that compromise the use of digital technologies is different depending on the professors' area of knowledge. Thus, it follows, as an implication of this study, that universities must increase their training plans for professors in terms of digital training and adapt them to the specificities of the area of knowledge.

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References

- Alharbi, B. A., Ibrahem, U. M., Moussa, M. A., et al. (2022). COVID-19 the Gateway for Future Learning: The Impact of Online Teaching on the Future Learning Environment. *Education Sciences*, 12(12), 917. <https://doi.org/10.3390/educsci12120917>
- Antón-Sancho, Á., & Sánchez-Calvo, M. (2022). Influence of Knowledge Area on the Use of Digital Tools during the COVID-19 Pandemic among Latin American Professors. *Education Sciences*, 12(9), 635. <https://doi.org/10.3390/educsci12090635>
- Antón-Sancho, A., Fernández-Arias, P., & Vergara, D. (2024). Arts professors' perception of the didactic use of virtual reality. *International Journal of Instruction*, 17(3), 19–36.
- Antón-Sancho, Á., Fernández-Arias, P., & Vergara-Rodríguez, D. (2023). Impact of the covid-19 pandemic on the use of ICT tools in science and technology education. *Journal of Technology and Science Education*, 13(1), 130. <https://doi.org/10.3926/jotse.1860>
- Antón-Sancho, Á., Vergara, D., Lampropoulos, G., et al. (2023). Digital generation influence on the Post-COVID-19 use of digital technologies in engineering education: A statistical study. *Electronics*, 12(19), 3989. <https://doi.org/10.3390/electronics12193989>
- Basilotta-Gómez-Pablos, V., Matarranz, M., Casado-Aranda, L. A., et al. (2022). Teachers' digital competencies in higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education*, 19, 8. <https://doi.org/10.1186/s41239-021-00312-8>
- Bond, M. (2020). Schools and emergency remote education during the COVID-19 pandemic: A living rapid systematic review. *Asian Journal of Distance Education*, 15(2), 191–247.
- Bouziane, A., Tahri, W., & Bouziane, K. (2023). Satisfaction and acceptance of ICT in learning activities during COVID19: The case of Moroccan students. In: Tomczyk, Ł. (editor). *New Media Pedagogy: Research Trends, Methodological Challenges and Successful Implementations*. Springer, Cham. https://doi.org/10.1007/978-3-031-44581-1_18
- Cabero-Almenara, J., Guillén-Gámez, F. D., Ruiz-Palmero, J., et al. (2021). Digital competence of higher education professor according to DigCompEdu. Statistical research methods with ANOVA between fields of knowledge in different age ranges. *Education and Information Technologies*, 26, 4691–4708. <https://doi.org/10.1007/s10639-021-10476-5>
- Cifuentes, G. A., & Herrera-Velásquez, D. A. (2019). Scale development and validation to measure institutional conditions to promote educational innovation with ICT. *Education Policy Analysis Archives*, 27, 88. <https://doi.org/10.14507/epaa.27.3779>
- Esteve-Mon, F. M., Llopis-Nebot, M. Á., & Adell-Segura, J. (2020). Digital teaching competence of university teachers: A systematic review of the literature. *IEEE Revista Iberoamericana de Tecnologías Del Aprendizaje*, 15(4), 399–406. <https://doi.org/10.1109/rita.2020.3033225>
- Ferri, F., Grifoni, P., & Guzzo, T. (2020). Online learning and emergency remote teaching: Opportunities and challenges in emergency situations. *Societies*, 10(4), 86. <https://doi.org/10.3390/soc10040086>
- Garrote Jurado, R., Pettersson, T., Regueiro Gomez, A., et al. (2014). Classification of the features in learning management systems. In: *Proceedings of the XVII Scientific Convention on Engineering and Architecture; 24–28 November 2014; Havana City, Cuba*.
- Gómez-Poyato, M. J., Eito-Mateo, A., Mira-Tamayo, D. C., et al. (2022). Digital skills, ICTs and students' needs: A case study in social work degree, university of zaragoza (Aragón-Spain). *Education Sciences*, 12(7), 443. <https://doi.org/10.3390/educsci12070443>
- Hu, M., & Li, H. (2017). Student engagement in online learning: A review. In: *Proceedings of the 2017 International Symposium on Educational Technology (ISET)*. <https://doi.org/10.1109/iset.2017.17>
- Jorge-Vázquez, J., Nández Alonso, S. L., Fierro Saltos, W. R., et al. (2021). Assessment of digital competencies of university faculty and their conditioning factors: Case study in a technological adoption context. *Education Sciences*, 11(10), 637. <https://doi.org/10.3390/educsci11100637>
- Lampropoulos, G., & Admiraal, W. (2023). The impact of COVID-19 pandemic on primary, secondary, and k-12 education: A systematic review. *International Journal on Studies in Education*, 5(4), 348–440. <https://doi.org/10.46328/ijonse.161>
- Liesa-Orús, M., Latorre-Coscolluela, C., Vázquez-Toledo, S., et al. (2020). The technological challenge facing higher education professors: Perceptions of ICT tools for developing 21st century skills. *Sustainability*, 12(13), 5339. <https://doi.org/10.3390/su12135339>
- Núñez-Canal, M., Obesso, M. de las M. de, et al. (2022). New challenges in higher education: A study of the digital competence

- of educators in covid times. *Technological Forecasting and Social Change*, 174, 121270.
<https://doi.org/10.1016/j.techfore.2021.121270>
- Pathiranage, A. & Karunaratne, T. (2023). Teachers' agency in technology for education in pre- and post-COVID-19 periods: A systematic literature review. *Education Sciences*, 13, 917. <https://doi.org/10.3390/educsci13090917>
- Ramos-Pla, A., Reese, L., Arce, C., et al. (2022). Teaching online: Lessons learned about methodological strategies in postgraduate studies. *Education Sciences*, 12, 688. <https://doi.org/10.3390/educsci12100688>
- Saif, S. M., Ansarullah, S. I., Ben Othman, M. T., et al. (2022). Impact of ICT in modernizing the global education industry to yield better academic outreach. *Sustainability*, 14(11), 6884. <https://doi.org/10.3390/su14116884>
- Salame, I. I., Gomes, V., Moreira, M. K., et al. (2023). Impact of the digitization of teaching on undergraduate students as the result of the Covid-19 pandemic and transitioning to online learning. *International Journal of Instruction*, 16(3), 343–362. <https://doi.org/10.29333/iji.2023.16319a>
- Simonson, M., & Schlosser, L. A. (2009). *Distance education: Definition and glossary of terms third edition* 3rd edition. Information Age Publishing.
- Sormunen, M., Heikkilä, A., Salminen, L., et al. (2021). Learning outcomes of digital learning interventions in higher education. *CIN: Computers, Informatics, Nursing*, 40(3), 154–164. <https://doi.org/10.1097/cin.0000000000000797>
- Turst, T., Whalen, J. (2020). Should teachers be trained in emergency remote teaching? Lessons learned from the COVID-19 pandemic. *Journal of Technology and Teacher Education*, 28(2), 189–199.
- UNESCO Institute for Statistics. (2012). *International Standard Classification of Education ISCED 2011*. UNESCO-UIS. Available online: <http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-educationisced-2011-en.pdf> (accessed on 9 January 2024).
- Vargas-Merino, J.A., Olórtegui-Alcalde, L.M., Córdova-Berona, H.A., et al. (2022). Information and communication technologies in Peruvian university students: A confirmatory analysis of their frequency and extent of use. *Education Sciences*, 12, 886. <https://doi.org/10.3390/educsci12120886>
- Vergara, D., Antón-Sancho, Á., Dávila, L.P., et al. (2022). Virtual reality as a didactic resource from the perspective of engineering teachers. *Computer Applications in Engineering Education*, 30, 1086–1101. <https://doi.org/10.1002/cae.22504>
- Vergara, D., Antón-Sancho, Á., & Fernández-Arias, P. (2023a). Gender gaps in the impact of the pandemic on the use of ICT in higher education. *Review of Education*, 11(3). <https://doi.org/10.1002/rev3.3439>
- Vergara, D., Antón-Sancho, Á., Fernández-Arias, P. (2023b). Engineering professors' habits: Didactic use of Information and Communication Technologies (ICT). *Education and Information Technologies*; in press. <https://doi.org/10.1007/s10639-023-12110-y>
- Vergara-Rodríguez, D., Concha, N. U. R., Solis, R. M., et al. (2022). Use of ICT tools in higher education in Peru during the COVID-19 pandemic. In: *Proceedings of the 2022 XII International Conference on Virtual Campus (JICV)*. <https://doi.org/10.1109/jicv56113.2022.9934616>
- Wallace, R. M. (2003). Online learning in higher education: A review of research on interactions among teachers and students. *Education, Communication & Information*, 3(2), 241–280. <https://doi.org/10.1080/14636310303143>

Appendix

The average frequencies of use of the different families of ICT tools are shown in **Table A1** to **Table A5** for each of the knowledge areas considered.

Table A1. Average frequency of use (out of 5) of the different families of ICT tools among Sciences professors and percentage rates of increase.

Family of tools	Pre-pandemic	Post-pandemic	Increase (%)
Interaction	2.99	3.88	29.77
Communication	2.88	3.70	28.47
Sharing	3.50	3.88	10.86
Evaluation	3.03	3.83	26.40

Table A2. Average frequency of use (out of 5) of the different families of ICT tools among Engineering professors and percentage rates of increase.

Family of tools	Pre-pandemic	Post-pandemic	Increase (%)
Interaction	2.93	3.86	31.74
Communication	2.73	3.75	37.26
Sharing	3.41	3.92	14.96
Evaluation	2.76	3.82	38.41

Table A3. Average frequency of use (out of 5) of the different families of ICT tools among Health Sciences professors and percentage rates of increase.

Family of tools	Pre-pandemic	Post-pandemic	Increase (%)
Interaction	2.84	3.97	39.79
Communication	2.53	3.56	40.71
Sharing	3.03	3.88	28.05
Evaluation	2.31	3.75	62.34

Table A4. Average frequency of use (out of 5) of the different families of ICT tools among Humanities professors and percentage rates of increase.

Family of tools	Pre-pandemic	Post-pandemic	Increase (%)
Interaction	2.54	3.85	51.57
Communication	2.55	3.81	49.41
Sharing	3.25	3.89	19.69
Evaluation	2.68	3.64	35.82

Table A5. Average frequency of use (out of 5) of the different families of ICT tools among Social Sciences professors and percentage rates of increase.

Family of tools	Pre-pandemic	Post-pandemic	Increase (%)
Interaction	2.80	3.77	34.64
Communication	2.59	3.78	45.95
Sharing	3.27	3.81	16.51
Evaluation	2.67	3.66	37.08