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IMPACT OF THE COVID-19 PANDEMIC ON THE USE OF ICT TOOLS IN SCIENCE AND TECHNOLOGY EDUCATION

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Abstract

This article analyzes the self-concept about digital competence in university professors of Sciences, Health Sciences and Engineering and the impact that the COVID-19 pandemic has had on the Information and Communication Technologies (ICT) use habits of professors in these areas. For this purpose, a survey designed by the authors was completed by 340 university professors in the aforementioned areas. Based on the answers obtained from this survey, a descriptive quantitative analysis of the assessments of the self-concept of digital competence and training of the participants, of the didactic use of ICT and the frequency of their use before and after the pandemic has been carried out. The results showed that the digital competence of the professors is intermediate, but their training is valued as low, especially in Sciences and Health Sciences. The assessment of ICT is very good. The pandemic has caused a generalized increase in the use of ICT, mainly in Health Sciences, which is the area in which university students were most reluctant to use them. In addition, a gender gap which did not exist before the pandemic has been generated favoring females in the use of ICT in Science and Engineering. An age-based digital gap that existed before the pandemic has also been corrected in Health Sciences.

Keywords – Didactic resource, Digital learning environment, Digital resource, Virtual environment, Science education, Healthcare, Health education, Engineering education.

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1. Introduction

The current digital era is characterized by technological development and digital migration of many activities and processes that affect the life of societies and countries (Shepherd, 2004). The so-called Information and Communication Technologies (ICT) play a leading role in this progressive technification. ICTs offer a wide range of tools and resources for accessing, managing, and transmitting information, as well as transforming and analyzing data. Part of their usefulness lies in their applicability as support for training activities at all educational levels and areas of knowledge (Liesa-Orús, Latorre-Cosculluela, Vázquez-Toledo & Sierra-Sánchez, 2020; Saif, Ansarullah, Ben-Othman, Alshmrany, Shafiq & Hamam, 2022). Its use in higher education has increased because of the intensification of the use of virtual learning environments, derived from the COVID-19 pandemic (Sormunen, Heikkilä, Salminen, Vauhkonen & Saaranen, 2022), whose onset can be placed in the first quarter of 2020. In higher education, prior to the pandemic ICT was specifically targeted learning, i.e., learning was mainly about ICT, but learning through ICT was done to a lesser extent. In contrast, during the pandemic, ICT became fundamental tools for performing tasks, searching, collecting, and communicating data, enabling students to acquire all types of learning, and enabling the evaluation of such learning (Batra & Kumar, 2022). ICT suddenly became cognitive learning tools, promoting cognitive reflection and favoring students' mental representations (Jonassen, 2000). In the specific case of the Latin American and Caribbean region, which is the subject of this study, in the first semester of the year 2022, face-to-face activities in universities resumed (UNESCO-IESALC, 2020). The pace of reopening varied according to the progress of vaccination in each country and the protocols approved by the respective governments. However, in a significant part of them, this reopening has been partial, maintaining a hybrid modality of studies, which combines the use of virtual environments with face-to-face activities, after having resumed on-site activities (UNESCO-IESALC, 2020). This fact has led to a global phenomenon of methodological shift on the part of professors, since the use of ICT entails the adoption of a constructivist approach to learning, centered on the learner and that can be carried out at any time and place (Dubey & Kanvaria, 2020).

To fully exploit the didactic usefulness of ICT, it is required to identify the learning objectives and match the digital tools to the achievement of those objectives (Smyrnova-Trybulska, Morze & Varchenko-Trotsenko, 2022). Consequently, as different subject areas have different learning objectives and outcomes, the way ICT should be applied in the classroom and the type of resources that teachers should use depends on the subject area (Antón-Sancho, Vergara, Fernández-Arias & Ariza-Echeverri, 2022c). In the case of higher education in the different sciences and in engineering, a correct integration of ICT involves the incorporation of resources that make it possible to illustrate reasoning in real time or to combine lessons with laboratory experimentation (La-Valle, McFarlane & Brawn, 2003).

The digitization of scientific and technical higher education has some limitations, such as access to the use of ICT by students –something that is not guaranteed, especially in certain geographical areas–, the availability of appropriate infrastructure by universities, or dependence on the evolution of technological development (Cifuentes & Herrera-Velásquez, 2019). In this sense, one of the main limitations is the need for high digital competence on the part of professors and their specific training on how to pedagogically connect technologies with learning objectives (Bingimlas, 2009; Aina, 2013), aspects that directly influence student learning (Guillén-Gámez & Mayorga-Fernández, 2020; Núñez-Canal, De-Obesso & Pérez-Rivero, 2022).

The economic investment that governments and universities should make for the implementation of these ICT is another constraint, especially in emerging economies (Zhang, Khan, Dagar, Saeed & Zafar, 2022). In the specific case of Latin American and Caribbean countries, the focus of this study, this investment extends both to the strengthening of structures and equipment and to the incorporation of human capital (Ngwenyama & Morawczynski, 2009). Likewise, the literature frequently specifies that the digital competence of university professors in Latin America should be prioritized within the digitization efforts of universities (Antón-Sancho, Vergara & Fernández-Arias, 2021a; Jorge-Vázquez, Náñez-Alonso, Fierro-Saltos & Pacheco-Mendoza, 2021).

This paper conducts quantitative research on the assessment made by Latin American science and engineering university professors about the didactic use of ICT, their own digital competence, and the impact that the COVID-19 pandemic has had on their habits of using ICT tools in their teaching work. To this end, a survey designed by the authors was used as a tool for data acquisition from a population of 340 Latin American university professors. The study involved professors from three areas of knowledge –Science, Health Sciences and Engineering– and a comparison was made between the three areas in terms of the impact that the pandemic has had on the frequency of ICT use in the different academic activities. The existence of digital gaps by gender or age in the assessments of professors in each of the areas mentioned is also studied. The aim is to increase collective knowledge about the changes caused by the COVID-19 pandemic in the process of digitalization of higher education in the field of science and engineering and to provide recommendations, specific to each scientific-technical area, to help professors and universities in this process.

In the preceding literature there are studies focused on the analysis of the digital competence of professors in a specific area of knowledge (Vergara, Antón-Sancho, Dávila & Fernández-Arias, 2022a), or that analyze the influence of certain sociological factors, such as age or the digital generation (Antón-Sancho, Fernández-Arias & Vergara, 2022a), but there is a lack of studies that analyze the existence of gaps in this regard between different areas of knowledge. The main novelty of the present work is precisely that it explores the existence of gaps in digital competence and ICT use habits of professors in different areas of science and technology higher education, including the different ways in which the digital gender gap behaves according to the specific area of knowledge.

2. Literature Review

2.1. ICT in Science and Technology Higher Education: Families of ICT and Didactic Uses

The behaviorist theory that understood the learning of science and technology as a process of assimilation and exercise with a set of symbolic objects governed by rules is being replaced by a more constructivist approach to learning (Leng & Hoong, 2009). This new perspective, together with the progressive incorporation of digital technologies into all areas of social life, has led to a global phenomenon of technification of higher education in recent years (Spante, Hashemi, Lundin & Algers, 2018). Since 2016, the number of publications on digitization of higher education institutions has increased every year (Benavides, Tamayo-Arias, Arango-Serna, Branch-Bedoya & Burgos, 2020). The role of ICT in scientific and technical higher education is to generate environments for active learning and the development of concepts from the most experimental, graphic, and visual approach as possible, with a certain prevalence of cooperative and collaborative work, and that are at the forefront of the technological revolution characteristic of the fourth industrial revolution (Gutiérrez, Pérez & Munguía, 2022). Their use, however, has been lower in science and engineering education than in other areas due to the complexity of transferring their specific concepts to digital environments and the need for experimentation in these degrees, which requires incorporating tools such as computer graphics (Wang, 2011; Suselo, Wünsche & Luxton-Reilly, 2019; Fedotov, Zakharova & Alymova, 2022), virtual and augmented reality (Vergara, Sánchez, Garcinuño, Rubio, Extremera & Gómez, 2019; Extremera, Vergara, Dávila & Rubio, 2020; Vergara, Fernández-Arias, Extremera, Dávila & Rubio, 2022b; Extremera, Vergara, Rodríguez & Dávila, 2022), computational dynamics (Potkonjak, Gardner, Callaghan, Mattila, Guetl, Petrović et al., 2016), or clinical simulations (Foronda, Godsall & Trybulski, 2013).

There has been a great global effort in recent years, before and during the pandemic, to encourage the integration of ICT tools into the dynamics of higher education science and engineering courses. This progressive impulse has led to the development of audiovisual resources, such as data capture and processing tools, virtual laboratories, or multimedia software for process simulation (McFarlane & Sakellariou, 2002; Rocha-Fernandes, Rodrigues & Rosa-Ferreira, 2019), the use of material and content sharing resources –including social networks– and virtual platforms that allow working through learning communities (Wright & Woolner, 2011; Willengton & Ireson, 2012; Lin, Lin & Chou, 2012; Oproiu, 2015; Singh, 2022). In this sense, the COVID-19 pandemic has led to the acceleration of the described digitization process forced by the virtualization requirements resulting from the restrictions that were imposed. The reception of this digital migration was high in Engineering students, but moderate in science students (Malkawi, Bawaneh & Bawa’aneh, 2021). On the other hand, undergraduates in Health Sciences were the least receptive to the digitalization caused by the pandemic because they believe that practical and clinical skills are best developed in traditional face-to-face environments (Abbasi, Ahmed, Sajjad, Alshahrani, Saeed, Sarfaraz et al., 2020; Osmani, 2021).

Numerous classifications of ICT resources that can be used in higher education appear in the literature. The approach from which these classifications are constructed is diverse. Some of them, such as that of

Yot-Domínguez and Marcelo (2017), are based on the theory of self-regulated learning (Marcelo & Rijo, 2019), in which the student organizes and structures the entire learning process. Other works classify ICT tools according to their applicability to different academic activities from the perspective of the professor's activity, which is more in line with the objectives of the present research. Thus, Badia-Garganté, Meneses-Naranjo and Garcia-Tamarit (2015) propose two taxonomies, focused respectively on professor's activity and student's activity. According to the professor's role, there would be two large families of ICT: content technologies, and interaction technologies. The former would be aimed at the presentation, sharing and development of content during classes and the latter at maintaining adequate communication with the rest of the teaching staff and students, for monitoring the learning process and evaluation (Table 1).

Academic activity	**ICT use**	**Example**
Content technologies	Support oral presentations of contents	Word processor
	Present contents through multimedia systems	Video creating
	Tutorials with students	Online platforms
	Show useful tools to students	Microsoft Office®
Interaction technologies	Dynamize virtual classes	Moodle®, Delicious®
	Communicate with students	Skype®, e-mail
	Monitor the progress of the learning process	E-portfolio, Self-assessment
	Provide guidelines to facilitate learning	Intelligent tutoring system

Table 1. Classification of ICT tools for didactic use in higher education from the perspective of the professor's teaching activity (Badiá-Garganté et al., 2015)

The classification by Peres and Pimenta (2011), also classic, distinguishes four types of ICT for didactic use in higher education: (i) content production tools, such as Prezi® or Power Point® (Peres, Moreira & Mesquita, 2018); (ii) communication tools, such as Skype®, Facebook® (Marcelo & Rijo, 2019), WhatsApp®, Telegram®, or Twitter® (Yadav, 2021); (iii) sharing content tools, such as YouTube® (Szeto & Cheng, 2014), Instagram® (Mohd-Jamil, Rusle, Zolkipli & Mohd-Shaharanee, 2021), or iVoox (Hojas-Hojas & García-del-Toro, 2020); (iv) reference management, such as Mendele® y or Zotero® (Peres et al., 2018); (v) and others, such as Moodle® or Blackboard® (Peres et al., 2018). The main limitation of this classification is the indefiniteness of the last category, which is referred to as "others".

Further classifications of ICT use in higher education follow the line of Peres and Pimenta's (2011) taxonomy. For example, the classification proposed by Xidirbaev and Abdurahmanov (2021), despite being based on self-regulated learning, follows, in its fundamental structure, that of Peres and Pimenta (2011), although it does not have a category that groups "other tools". Instead, it adds another family, referred to evaluation tools and monitoring of students' learning, where resources such as Quizziz, Socrative, Kahoot, Mentimeter, or Plickers can be included (Boonmoh, Jumpakate & Karpklon, 2021).

The literature presents few taxonomies of ICTs for teaching use in science and engineering higher education, but those that are found agree, in their general structure, with the classifications presented. Thus, Garrote-Jurado, Pattersson, Regueiro-Gómez and Scheja (2014) propose a classification of ICTs into four major families: (i) tools for distribution, which are resources for sharing material with students –it corresponds, essentially, with the third family of Peres and Pimenta (2011)–; (ii) tools for communication, which refers to resources for interaction with students and keeping tutorials –it is basically the second family of Peres and Pimenta (2011)–; (iii) tools for interaction, referring to the presentation of content and dynamization of classes that encourage active student participation and collaborative action, analogous to the first ICT family of Peres and Pimenta (2011); and (iv) tools for course administration, which, among others, aims at monitoring, follow-up and evaluation of students –it is essentially the last category introduced in the classification of Boonmoh et al. (2021)–.

The above taxonomies present some limitations. Among them, the fact that tools to support oral presentations in class, such as Prezi®, Power Point®, Slidesgo®, Powton®, Canva®, or Genially®, are integrated in the same category with those that serve to address content visually and interactively during classes, such as virtual learning tools for spatial visualization (Vergara, Rubio & Lorenzo, 2018) or virtual and augmented reality resources applied to virtual laboratories (Potkonjak et al., 2016; Vergara et al., 2022b). In addition, there is no distinction, among communication tools, between the two uses they can have: communication with students and with the rest of the professors. For the purposes of this research, it is interesting to make the distinctions. Therefore, based on the above taxonomies, the classification shown in Table 2 is proposed, which is in line with the objectives pursued by this research and serves as the basis for the construction of the research instrument of this study. This taxonomy is shown in parallel with the classifications that the literature presents and that have just been presented.

Family of ICT tools	Examples	Peres and Pimenta (2011) Boonmoh et al. (2021)	Garrote-Jurado et al. (2014)
Presentations for class	Power Point®, Prezi®	Content production	Interaction
ICT tools for class use	PDF-3D®, virtual lab		
Meetings with the staff	Google Meet®, Skype®	Communication	Communication
Tutorials	Blackboard®, Zoom®		
Content sharing	YouTube®, iVoox®	Sharing content	Distribution
Evaluation tools	Socrative®, Quizziz®, Google Forms®, Kahoot®	Others	Course administration

Table 2. Proposed classification of ICT tools for educational purposes in science and engineering higher education

Current research in the field of ICT integration in science and engineering higher education mainly follows two lines: (i) the analysis of the formative effectiveness of ICT resources and their acceptance by students; and (ii) the study of the competence for their use of the professors involved and the formative impact that the professor's digital competence has on the students. With respect to the first line, there are abundant descriptive and empirical studies that show how the use of different ICT tools improves students' learning and academic performance (García, Romero, Ceamanos & Lázaro, 2021), increases their motivation (Dai, Xiong, Zhao & He, 2022), and leads to an improvement in certain transversal competencies, such as communication skills (Reijenga & Roeling, 2009). In addition, these didactic resources are generally welcomed by students as motivational elements that promote learning (Vergara et al., 2022b). It has also been proved that the use of ICT tools as dynamizing elements during classes increases student participation, mainly when working on technical or experimental concepts, which are more easily manipulated than concepts of a more theoretical and abstract nature (Lucke, Dunn & Christie, 2017).

With respect to the second line, it has been shown that the self-concept of digital competence of science and technology professors influences the formative effectiveness of the didactic situations with ICT that they design (Alt, 2018). There is a great disparity in the results presented by the specialized literature concerning these digital skills. Indeed, within the field of science and technology, the specific area of knowledge –formal sciences and mathematics, experimental, medical, or technical education– influences the digital competence of professors, with engineering faculty having, in general, the best digital competence (Antón-Sancho et al., 2021a; Antón-Sancho, Vergara, Lamas-Álvarez & Fernández-Arias, 2021b; Fernández-Arias, Antón-Sancho, Vergara & Barrientos, 2021; Antón-Sancho et al., 2022c).

The literature also reports the existence of digital gaps due to the age of professors, so that older professors also express greater resistance to the implementation of ICT resources in educational activities and greater difficulty in their use (Basantes-Andrade, Cabezas-González & Casillas-Martín, 2020; Cabero-Almenara, Guillén-Gámez, Ruiz-Palmero & Palacios-Rodríguez, 2021; Antón-Sancho et al., 2022a). In this sense, some authors point out that the professor's previous training in the didactic use of ICTs and the experience they have in their use in the class are the most influential factors in achieving high efficacy in the training of students (Montoro, Hinojo-Lucena & Sánchez, 2015; Ferk-Savec, 2017; Cubeles & Riu, 2018). Likewise, the affective domain variables linked to the pandemic –stress, anxiety, or nervousness– have also had an impact on the process of digitalization of training activities that the pandemic has forced in recent months (Rangel-Pérez, Gato-Bermúdez, Musicco-Nombela & Ruiz-Alberdi, 2021; Vergara-Rodríguez, Antón-Sancho & Fernández-Arias, 2022).

In addition, it is important to consider the geographical factor, due to the additional difficulty that may exist in areas with medium or low levels of digitization for access to technologies (Rodríguez-Abitia, Martínez-Pérez, Ramirez-Montoya & Lopez-Caudana, 2020; Antón-Sancho, Vergara & Fernández-Arias 2022b). The geographical area is also an influential variable in other ways that condition the use of ICT in higher education. For example, societies that are more culturally polymorphic usually present differences by culture or race in terms of access to and use of digital technologies, which penalizes minority or less favored sectors of society, as occurs in the United States between African Americans and Caucasian Americans (Jackson, Zhao, Kolenic, Fitzgerald, Harold & Eye, 2008).

The literature supports that any gender gaps in the use of ICT among university professors, regardless of the area of knowledge, also depend on the geographical area. Thus, in Europe it is common to find studies that do not find gender gaps in higher education (Sánchez-Prieto, Trujillo-Torres, Gómez-García & Gómez-García, 2020). In fact, some studies place female professors in a potentially better position than males in terms of the ability and use of ICT in the classroom, given that they are attributed with greater emotional intelligence (Papoutsi, Chaidi, Drigas, Skianis & Karagiannidis, 2022), a characteristic that favors the use of ICT because it regulates negative feelings of digital stress and increases self-confidence (Shukla & Chatterjee, 2021). In contrast, in some geographical areas, such as Asia or Latin America, which is the focus of this paper, there is still a gender digital gap that affects access to and use of digital technologies. In this sense, females tend to encounter greater difficulties, due to cultural elements rooted in the corresponding societies, which are specific to the area and particularly affect scientific and technical higher education (Contreras-Ortiz, Villa-Ramírez, Osorio-Delvalle & Ojeda-Caicedo, 2020; Palomares-Ruiz, Cebrián, López-Parra & García-Toledano, 2020; Peña, Olmedo-Torre, Alcaraz, Chavez-Dominguez, López & Mujica, 2022). Among these cultural elements are lifestyles and family customs, or stereotypes concerning the identification of certain activities or professions with certain genders, which usually link males to scientific-technical areas and to the use of digital technologies (Alam, 2022).

2.2. Digital Competence and ICT Integration in Latin American Universities

According to the latest data from the Inter-American Development Bank and the Tecnológico de Monterrey, most Latin American university professors consider that the didactic use of ICTs is very positive for achieving the learning objectives sought in each field of knowledge (Arias-Ortiz, Escamilla, López & Peña, 2020). However, the literature identifies numerous limitations to the progress of digitization of higher education in Latin America. These include difficulties in universal access to the Internet (Grazzi & Vergara, 2014) and insufficient funding in universities for the acquisition of the required technologies (Kazemikhasragh & Buoni-Pineda, 2022; Motta & González-Farias, 2022). Although it is a general phenomenon, the latter aspect particularly affects some specific knowledge areas, such as medicine and nursing (Cassiani, Wilson, Mikael, Morán-Peña, Zarate-Grajales, McCreary et al., 2017). The above data are supported by the specialized scientific literature (Ngwenyama & Morawczynski, 2009). All this explains why the use of ICT in Latin America is low in general (Brynjolfsson & Hitt, 2000; 2003) and, particularly, in the educational sector (Quiroga-Parra, Torrent-Sellens & Murcia-Zorrilla, 2017).

The specialized literature indicates that, in general, the levels of university faculty digital skills is mediocre and sometimes deficient, which has been observed especially after the process of digitization of higher education resulting from the pandemic (Garzón-Artacho, Sola-Martínez, Romero-Rodríguez & Gómez-García, 2021; Guillén-Gámez et al., 2020; Tsegay, Ashraf, Perveen & Zegergish, 2022). These deficiencies in digital competence have been observed in the development of different didactic activities involving the use of ICT, such as the design and creation of content and materials. However, in this sense there is some divergence among the results presented by the literature, because some works value as sufficient these digital skills in university professors (Cabero-Almenara & Díaz, 2018; Yáñez-de-Aldecoa & Gómez-Trigueros, 2022). The works that analyze the self-perception that university teachers have about their own digital competence frequently conclude that teachers recognize that their digital skills can be improved (Antón-Sancho et al., 2021b). Likewise, university students perceive that the low digital competence of their professors is one of the main limitations for the development of their own digital competence and for the integration of ICT in the dynamics of lectures (Gómez-Poyato, Eito-Mateo, Mira-Tamayo & Matías-Solanilla, 2022).

The literature also recognizes the existence of factors that limit the process of acquisition of digital skills by both teachers and students, such as the high cost that some authors attribute to the implementation of ICT by universities. This causes the emergence of difficulties in accessing digital technologies, especially among teachers and students from certain geographical areas plagued by social and economic inequalities, such as some areas of Latin America (Cinotti, Emili & Ferrari, 2018; Hordatt & Hayness-Brown, 2021). The specialized literature also identifies some sociological or academic factors of university teachers that significantly influence the acquisition of their digital competencies. Among them, the most frequently studied by the literature are gender and teaching experience. The results show that males are usually better prepared for the use of ICT in the classroom and feel more confident. This gender gap is rooted in cultural aspects, such as gender stereotypes, and consequently strongly depends on the geographical area concerned (Ilomäki, 2011; Basantes-Andrade, et al. 2020).

The results of the previous works show that the integration of digital tools and the use of methodologies that use ICT entails a subsequent increase in students' digital skills (Jorge-Vázquez et al., 2021; Zhao, Pinto-Llorente & Sánchez-Gómez, 2021), as well as transversal skills, such as communication or collaborative ones (García-Martínez, Rosa-Napal, Romero-Tabeayo, López-Calvo & Fuentes-Abeledo, 2020; Burgos-Videla, Castillo-Rojas, López-Meneses & Martínez, 2021). The literature perceives as an essential measure the increase in faculty training in digital competence by universities, both for the digital education of students and for the digital training of professors (Cabero-Almenara, Gutiérrez-Castillo, Palacios-Rodríguez & Barroso-Osuna, 2020; Cored-Bandrés, Liesa-Orús, Vázquez-Toledo, Latorre-Cosculluela & Anzano-Oto, 2021).

Latin American university professors understand, in general, that their training is insufficient to take maximum advantage of the didactic potential of ICT resources (Vergara et al., 2022a). This is, in fact, the main limitation that professors find for the integration of ICT in the teaching activities (Arias-Ortiz et al., 2020). For that reason, the specialized literature suggests the need for universities to design training strategies to increase the digital competence of professors (Cubeles & Riu, 2018; Aquino, Zuta & Cao, 2021; Salas-Pilco, Yang & Zhang, 2022; Santo, Días-Trinidade & Reis, 2022). In some specific areas, such as Health Sciences, the literature also identifies a certain opposition on the part of students to the use of ICT, although this resistance decreases to the extent that professors become more familiar with the technologies they are using and apply them with appropriate pedagogical criteria (Muñoz-Cano, Córdova, & Priego, 2012).

The COVID-19 pandemic and the digital migration of educational processes that it caused have led to an evident increase in the use of ICT in the field of higher education. This fact has also highlighted the main limitations of this digitalization in Latin American universities, such as the lack of connectivity or the scarce specific training of the teaching staff (Contreras, Picazo, Cordero-Hidalgo & Chaparro-Medina, 2021).

The specialized literature suggests that the integration of ICT in Latin American higher education is influenced by a gender gap that penalizes females in terms of the use of ICT resources. This gender gap is conditioned by the characteristics and social norms that affect, in general, emerging economies and that generate adverse economic, educational, and cultural conditions for females (Hilbert, 2011; García-Holgado, Camacho-Díaz & García-Peñalvo, 2019). This phenomenon affects the situation of females in universities, especially in science and technology degrees, both in terms of access to higher studies in the scientific-technical field (Holanda & Da-Silva, 2022) and in the use of digital technologies by female students and professors (García-Holgado, Deco, Bredegal-Alpaca, Bender & Villalba-Condori, 2020; Ramírez-Lozano, Bridshaw-Araya & Brito-Ochoa, 2022). The correction of these gender-based differences is a concern of the scientific literature, which leads to the design of mechanisms to ensure equality, usually involving the promotion of the use of digital technologies by females and greater investment in this regard by the responsible institutions, mainly in the field of faculty training and the equipment of university institutions (Marín-Raventós & Calderón-Campos, 2016).

3. Methodology

3.1. Participants

A total of 340 Latin American university professors participated in this research, who were chosen by a non-probabilistic convenience sampling process. All of them participated in a training session given by the authors and repeated every two weeks from October 2021 to June 2022. Attendance at the training course allows to assume that the professors had a sufficient and homogeneous knowledge of the elementary concepts related to ICT at the time of participating in the study. The target population consisted of professors specialized in some area of science (life sciences, physical sciences, mathematics, statistics, and computing), Health Sciences (medicine, medical and dental services, nursing, and social care and work), or Engineering, manufacturing, and construction (engineering, manufacturing, architecture and building), who teach in the corresponding area. These three knowledge areas correspond to ISCED fields of education 4, 7, and 5, respectively (UNESCO, 2011). Therefore, the criteria for inclusion in the study were the following: (i) being a professor at a Latin American university; (ii) being a specialist in one of the areas of Science, Health Sciences, or Engineering and teaching in that area; (iii) having participated in the training session on the didactic use of ICT given by the authors. Initially, 698 professors responded to the survey, of whom 358 were excluded because they were not involved in university education (41.90%) or were specialists in an area of knowledge other than those under consideration in this study (58.10%). Finally, 340 university professors from 15 Latin American countries were included in the research process: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Honduras, Mexico, Nicaragua, Panama, Peru, Puerto Rico, Dominican Republic, Uruguay, and Venezuela. The demographic distribution of the participating professors is shown in Table 3. This distribution by country is not homogeneous, since slightly more than half of the participating professors come from Argentina or Peru (chi-square = 777.85, df = 12, p-value < 0.0001).

Country	Number of participants	Proportion of the sample (%)
Peru	145	42.65
Argentina	53	15.59
Mexico	30	8.82
Ecuador	29	8.53
Chile	24	7.06
Colombia	21	6.18
Brazil	12	3.53
Nicaragua	9	2.65
Puerto Rico	5	1.47
Dominican Republic	4	1.18
Honduras	3	0.88
Panama	3	0.88
Bolivia	2	0.59

Table 3. Demographic distribution of participants

3.2. Objectives and Variables

This research seeks to achieve the following objectives: (i) to describe the distribution of the participating professors by knowledge areas and, within each area, by gender and age; (ii) to analyze the self-perception of digital skills and the training received on ICT in their institution; (iii) to study the assessment made by the participating professors of the didactic use of ICT; (iv) to identify differences by gender or age in the above assessments; (v) to study the impact of the COVID-19 pandemic on the frequency of didactic use of ICT among the participating Science, Health Sciences and Engineering professors; (vi) to check whether there are differences by gender or age in the aforementioned impact.

Consequently, three independent variables are differentiated in this study. The main independent variable is the area of knowledge, which is nominal trichotomous and its possible values are Science, Health Sciences or Engineering. The secondary independent variables are gender and age. The gender variable is nominal dichotomous, with values male or female. The ages have been distributed in five ranges of 10 years each, starting at 25 years old. Attributing values 1 to 5 to each of these ranges, in increasing order with age, this variable has been taken as an ordinal variable with values on a scale of 1 to 5.

Three dependent variables were defined, all corresponding to assessments expressed by the participants: (V1) self-concept of digital competence and the training received in ICT in the own institution; (V2) didactic usefulness of the use of ICT; and (V3) frequency of use of the different ICT tools in the teaching activities. All the dependent variables were measured on a Likert scale from 1 to 5, where 1 means the lowest self-concept or valuation and 5 means the highest.

3.3. Instrument

To achieve the above objectives, a 14-question survey was used (Table 4). The survey was originally designed by the authors for the purpose of this research. It is divided into two parts, depending on whether the questions ask for an assessment (first part) or an estimation of the frequency of ICT use (second part). The first part has two sections, each of which is used to value one of the dependent variables (V1) and (V2) of the theoretical model defined above. The second part asks to estimate the frequency of use of ICT resources in the different training activities indicated in each question (Table 2), prior to the appearance of COVID-19 and after the pandemic. All questions are measured on a Likert scale of 1 to 5. In the questions of the first part, 1 means the lowest valuation and 5 means a very high valuation for each aspect. For the questions in the second part, 1 means never and 5 means very often.

Part	Section	Question
1	Section 1.1: Knowledge and training	Updating in the didactic use of ICT in your area
		ICT knowledge
		Proficiency in ICT-specific terminology
		ICT training received at your institution
		Willingness to train in ICT in the future
	Section 1.2: Usefulness of ICT	Academic effectiveness
		Inclusiveness
		Student motivation
2	Frequency of use before and after COVID-19	Presentations for class
		ICT tools for class use
		Meetings with the teaching staff
		Tutorials with students
		Content sharing tools
		Evaluation tools

Table 4. Questions of the survey

3.4. Statistical Analysis

A statistical study of the answers given by the participants to the survey was carried out. Regarding the first part of the survey, an Exploratory Factor Analysis (EFA) of the responses with Varimax rotation was performed to confirm the proposed theoretical model of two sections, corresponding to two main dependent variables. The EFA is relevant for the purposes of this research because the survey was designed by the authors and, therefore, it is necessary to analyze the latent factors that explain it, as a way of validating it. In addition, the validation of the instrument was completed with an analysis of internal reliability and convergent validity, through the composite reliability (CR), Cronbach's alphas and average variance extracted (AVE) parameters. The distributions of the responses in this part were studied using the main descriptive statistics (mean, standard deviation, coefficient of variation and Pearson's skewness coefficient). The Lilliefors normality test showed that the answers to the questions in this part are not normally distributed, but it follows from Bartlett's test that they are distributed with homoscedasticity (i.e., they are uniformly distributed). Consequently, the Kruskal-Wallis nonparametric test was chosen to study the differences in the distributions of the responses to each assessment among the professors of the three subject areas of interest. Likewise, the Wilcoxon test for independent samples (with bilateral contrast) was used to identify digital gaps by gender within each knowledge area in the responses to this part. To check for age gaps in these responses, the Spearman correlation test (bilateral contrast) was used. Spearman's correlation coefficient was chosen because it is sensitive to nonlinear dependencies of the variables, unlike Pearson's correlation coefficient.

In the second part of the survey, which deals with assessing the frequency of ICT use before and after the COVID-19 pandemic, the Wilcoxon test for paired samples (with unilateral contrast) was used to check whether the increase in this use suggested by the responses was significant. This test was chosen after verifying, by means of the Lilliefors and Bartlett tests, that the responses are not normally distributed but are homoscedastic. The Kruskal-Wallis test was chosen to look for significant differences in the distributions of the frequencies of ICT didactic use among the three areas of knowledge considered, both before and after the pandemic. Finally, to identify gender or age gaps in the frequencies expressed, the Wilcoxon test for independent samples (bilateral contrast) and the Spearman correlation test, respectively, were used. A significance level of 0.05 was taken as the level of significance in all the hypothesis testing carried out.

4. Results

4.1. Distribution of Participants

The distributions of professors by knowledge areas, in Science (26.47%), Health Sciences (28.24%) and Engineering (45.29%) are not homogeneous (chi-square = 22.047; df = 2; p-value < 0.0001). There are most Engineering professors, which is almost half of the total sample, while the other half is distributed, approximately homogeneously, between the areas of Sciences and Health Sciences.

Pearson's test of independence proves that the distributions of participants by areas of knowledge and gender are statistically dependent, i.e., one variable varies between the different values of the other variable (chi-square = 21.3830; df = 2; p-value < 0.0001). Specifically, most professors in Science and Health Sciences are females, but they are in the minority in Engineering (Figure 1). Indeed, the distributions are approximately similar in the areas of Sciences and Health Sciences when the participants are differentiated by their gender. The area of knowledge and the age of the professors are also statistically dependent (chi-squared = 19.074; df = 8; p-value = 0.0145). The least heterogeneous age distribution is found in Health Sciences (Figure 2). Engineering area has the highest proportion of younger professors and the lowest of older professors. In Sciences area it is found the highest proportion of young professors and the lowest of older ones.

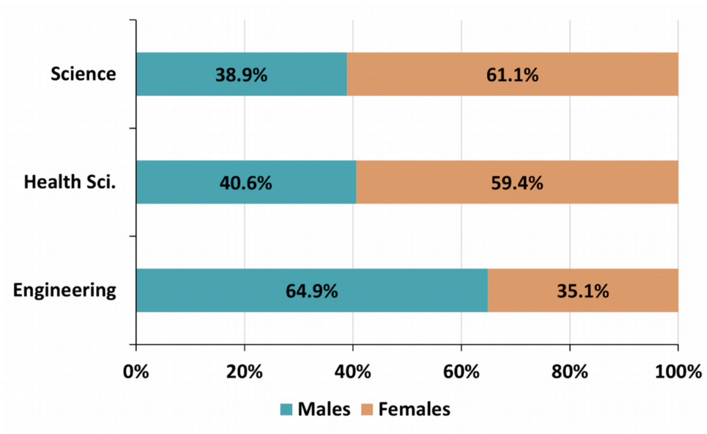

Figure 1. Distributions of the participants by area of knowledge and gender

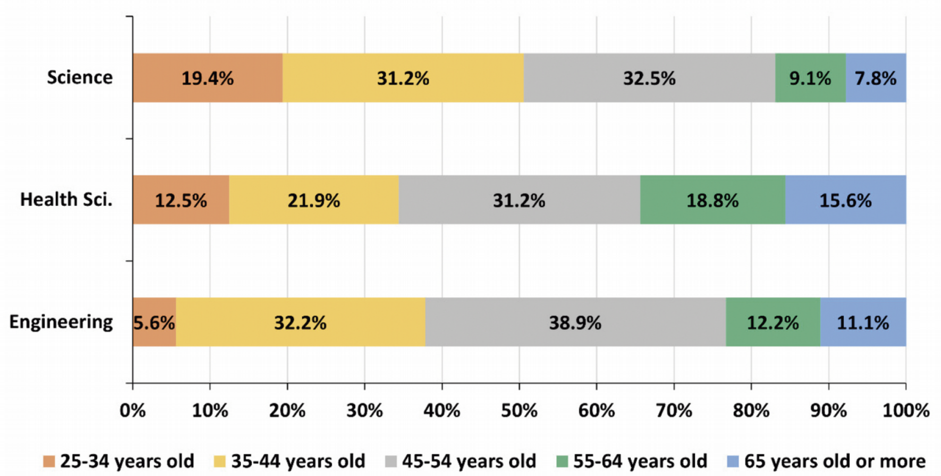

Figure 2. Distribution of participants by area of knowledge and age range

4.2. Digital Competence and ICT Assessment

The results of the EFA carried out on the first part of the survey (first eight questions) identify two latent factors that explain the responses and that correspond to the two sections of questions defined (Table 5). Thus, the theoretical model initially proposed on the existence of the two sections is confirmed. The first section assesses the digital teaching competence that the participating professors perceive of themselves, and their valuation of the digital training received in their institutions (questions 1 to 5). The second section provides the valuations that the professors make of the ICT tools for teaching purposes in terms of academic, motivational, and inclusive performance (questions 6 to 8). The model thus defined explains 64.5% of the total variance (Table 6).

Question	Section 1.1	Section 1.2
Updating in the didactic use of ICT in your area	0.721	
ICT knowledge	0.798	
Proficiency in ICT-specific terminology	0.781	
ICT training received at your institution	0.406	
Willingness to train in ICT in the future	0.443	
Academic effectiveness		0.891
Inclusiveness		0.752
Student motivation		0.610

Table 5. Factorial weights of the EFA when applied to the first part of the survey.

	Section 1.1	Section 1.2
Proportion Variance	0.383	0.262
Cumulative Variance	0.383	0.645

Table 6. Proportions of the variance explained by the defined scales.

Section	CR	Cronbach α	AVE
Section 1.1 (digital competence and ICT training)	0.7381	0.7627	0.5812
Section 1.2 (assessment of ICTs in teaching activities)	0.7930	0.8132	0.6047

Table 7. Cronbach's alphas, CR and AVE parameters.

Question	Mean	SD	CV (%)	Skewness
Updating in the didactic use of ICT	3.38	0.72	21.21	0.17
ICT knowledge	3.55	0.81	22.83	–0.24
Proficiency in ICT-specific terminology	3.66	0.84	22.89	–0.02
ICT training received at your institution	2.71	1.22	44.91	0.12
Willingness to train in ICT in the future	3.96	0.86	21.81	–0.70
Academic effectiveness	4.41	0.67	15.10	–0.82
Inclusiveness	4.31	0.67	15.48	–0.58
Student motivation	4.10	0.74	18.17	–0.46

Table 8. Descriptive statistics of the responses to the questions of the first part of the survey (SD: Standard deviation; CV: Coefficient of variation).

Since all the composite reliability parameters and Cronbach's alphas exceeded 0.7 (Table 7), it can be assumed that the defined sections have high levels of internal consistency (Taber, 2018). Likewise, all the AVE statistics exceeded 0.5, which confirm convergent validity, according to the Fornell-Larcker criterion (Shrestha, 2021).

Participants express having an intermediate level of knowledge and skills for the use of ICT in teaching contexts (Table 8). The assessment of the training received on the use of ICT is intermediate-low, but the willingness of professors to be trained is high. In the first section of questions, on digital teaching skills, the responses are more homogeneous than those on training received, which are the most dispersed, given that their variation is the highest. The mean valuations of ICT tools are high, and they are less dispersed than those of the digital competence section, which shows that there is a greater consensus in this regard. Lilliefors normality test shows that the responses to none of the questions are normally distributed. All the distributions have negative skewness, except for the responses on digital updating and training received (Table 8). This negative skewness is greater in the section of assessments of ICT.

When differentiated by areas of knowledge, Bartlett's test of difference of variances, applied with 2 degrees of freedom, shows that the responses in the sections on digital competence and assessment of ICT are distributed with homoscedasticity. The Kruskal-Wallis test with 2 degrees of freedom proves that there is a significant gap by knowledge area in the responses of the digital competence section, except in the one related to the willingness to be trained, but not in the ICT valuation section (Table 9). Engineering professors are the ones who report the greatest knowledge and training in ICT, and Health Sciences professors the least.

Among Engineering professors there are no significant gender gaps (Table 10). Nor are there any among Science professors, except for expressed knowledge of ICT, which is higher among females ($W = 778.5$; p-value = 0.0045). The largest gender gap is found among Health Sciences professors. Indeed, females manifest a lower knowledge of ICT terminology than males in this area ($W = 1458.0$; p-value = 0.0035) but have a higher predisposition to increase their digital competence ($W = 666.0$; p-value = 0.0004). In addition, female Health Sciences professors value the effectiveness of ICT use for academic performance more positively than male professors ($W = 778.5$; p-value = 0.0039).

Question	Science	Health Sci.	Engineering	K-squared	p-value
Updating in the use of ICT	3.28	3.03	3.65	48.1540	0.0000*
ICT knowledge	3.51	3.31	3.71	15.9470	0.0003*
ICT-specific terminology	3.78	3.16	3.91	52.7420	0.0000*
ICT training received	2.69	2.19	3.04	31.3430	0.0000*
Willingness to train in ICT	3.91	4.00	3.97	1.2400	0.5379
Academic effectiveness	4.33	4.56	4.36	5.3093	0.0703
Inclusiveness	4.32	4.38	4.27	0.6427	0.7252
Student motivation	4.22	3.97	4.10	4.8976	0.0864

Table 9. Mean valuations (out of 5) and results of the Kruskal-Wallis test with 2 degrees of freedom when the participants are differentiated by their area of knowledge (*$p < 0.05$).

Question	Science		Health Sci.		Engineering	
	Males	Females	Males	Females	Males	Females
Updating in the use of ICT	3.23	3.31	3.00	3.05	3.72	3.52
ICT knowledge	3.17*	3.73*	3.23	3.37	3.74	3.67
ICT-specific terminology	3.63	3.87	3.46*	2.95*	3.92	3.89
ICT training received	2.77	2.64	3.38	2.05	3.14	2.85
Willingness to train in ICT	3.77	4.00	3.69*	4.21*	3.96	4.00
Academic effectiveness	4.17	4.44	3.69*	4.21*	4.32	4.44
Inclusiveness	4.31	4.33	4.38	4.68	4.32	4.19
Student motivation	4.14	4.27	4.38	4.37	4.04	4.22

Table 10. Mean valuations (out of 5) by genders within each area of knowledge (*p-value < 0.05 in the bilateral Wilcoxon test for independent samples).

Question	Science	Health Sci.	Engineering
Updating in the use of ICT	0.0281	0.0513	–0.1303
ICT knowledge	–0.0637	–0.1530	0.1029
ICT-specific terminology	–0.0526	–0.2757*	–0.0723
ICT training received	–0.2686*	–0.0547	–0.1268
Willingness to train in ICT	–0.1137	–0.1342	0.1405
Academic effectiveness	–0.0002	–0.0596	0.0566
Inclusiveness	0.1772	–0.1530	0.0314
Student motivation	0.1486	–0.3024*	–0.0244

Table 11. Spearman correlation coefficients with respect to the age variable (*p-value < 0.05 in the bilateral Spearman correlation test)

Age does not significantly influence the self-perception of digital competence and ICT training of Engineering professors (Table 11). Among Science professors, the valuation of ICT training received decreases slightly with age (S = 154112; p-value = 0.0105). Among Health Sciences professors, older ones give lower ratings to their own knowledge of ICT terminology (S = 188094; p-value = 0.0065) and to the motivation caused by its use in students (S = 192027; p-value = 0.0027) than younger ones, although the influence is, once again, weak.

4.3. ICT Usage Habits Before and After the Pandemic

After the COVID-19 pandemic, the use of ICT resources has increased in all the teaching activities analyzed (Figure 3). The responses on the frequency of use of the different ICT tools are not normally distributed, but are uniformly distributed, as can be deduced from Bartlett's test applied with 2 degrees of freedom. The Wilcoxon test for paired samples (one-sided contrast) supports that all the increases in the frequency of didactic use of ICTs are statistically significant. The highest percentage increase is reached in the use of tools for evaluation (50.18%), followed by meetings with professors (48.12%), tutorials (44.01%), and the use of ICT to make the classes more dynamic (42.63%). The smallest increases were observed in the use of content sharing tools (28.21%) and presentations for class (16.06%). In both cases, the low increase is explained by the fact that they were the most frequently used tools before the pandemic by the participating professors. Currently, all ICT tools are used with very high frequencies, although the most frequently used tools are the same as those most used before the pandemic –presentations and sharing tools– and the least frequently used tools were also the least used before the pandemic –tutorials and evaluation tools–.

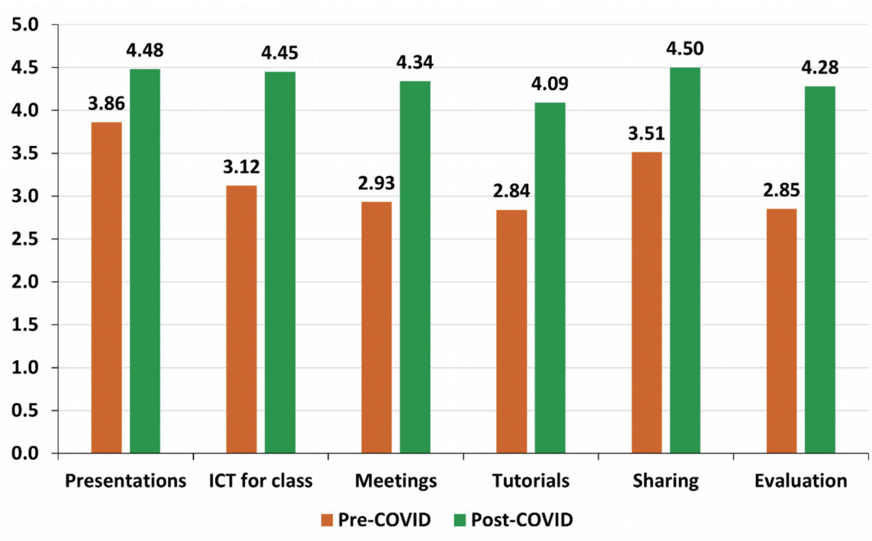

Figure 3. Mean valuations (out of 5) of the frequency of use of each ICT tool before and after the pandemic

Before the COVID-19 pandemic, the frequency of use of ICT tools in teaching activities was intermediate, with presentations for class being the most used resource in the three knowledge areas considered (Table 12). However, the Kruskal-Wallis rank sum test statistics with 2 degrees of freedom show that there are significant differences among the three knowledge areas in the frequencies of ICT use in all teaching activities, except for the use of ICT for class dynamization (Table 13). In all these activities, Science professors are the ones who report using ICT most frequently and Health Sciences the least frequently. After the COVID-19 pandemic, the use of ICT tools has grown in all aspects and in all areas. Regarding the use of evaluation tools, the pandemic has had the effect of reducing the differences that existed before COVID-19 in the frequency of their use among professors of Sciences, Health Sciences and Engineering, but there is still a gap between areas of knowledge regarding the use of ICT in the rest of the activities, except for the use of ICT for class use, which maintains homogeneity between areas. After the pandemic, it is the Engineering professors who report the highest frequency of use in all teaching activities, except for the use of ICT during classes. In any case, professors in the Health Sciences area report the greatest increase in the frequency of use of ICT tools in all teaching activities, followed by Engineering professors (Figure 4). The Wilcoxon test with one-sided contrast reveals that these increases in the frequency of ICT use are statistically significant in all the areas analyzed and in all aspects of teaching activity.

ICT tools	Science	Health Sci.	Engineering	Chi-squared	p-value
Presentations for class	4.01	3.63	3.92	9.4238	0.0090*
ICT tools for class use	3.13	2.94	3.22	3.4633	0.1770
Meetings with the staff	3.16	2.50	3.06	18.0960	0.0001*
Tutorials with students	2.97	2.56	2.94	7.7669	0.0206*
Content sharing tools	3.74	3.09	3.64	23.7320	0.0000*
Evaluation tools	3.18	2.38	2.96	25.6990	0.0000*

Table 12. Mean values (out of 5) of the frequency of use of each ICT tool before the pandemic in each area of knowledge and results of the Kruskal-Wallis test with 2 degrees of freedom (*p<0.05)

ICT tools	Science	Health Sci.	Engineering	Chi-squared	p-value
Presentations for class	4.32	4.41	4.56	9.0138	0.0110*
ICT tools for class use	4.38	4.53	4.51	4.4401	0.1086
Meetings with the staff	4.33	4.09	4.49	7.4156	0.0245*
Tutorials with students	3.96	3.94	4.26	10.0230	0.0067*
Content sharing tools	4.40	4.41	4.61	11.6280	0.0030*
Evaluation tools	4.22	4.22	4.35	5.3733	0.0681

Table 13. Mean values (out of 5) of the frequency of use of each ICT tool after the pandemic in each area of knowledge and results of the Kruskal-Wallis test with 2 degrees of freedom (*p<0.05)

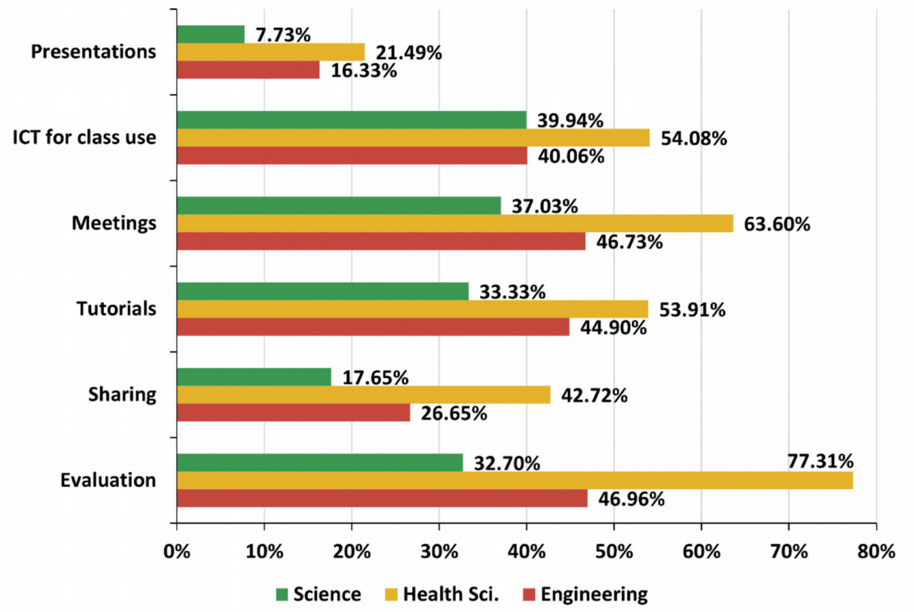

Figure 4. Percentage growth of the average frequency of use of each ICT tool in each area of knowledge after the pandemic compared to before the pandemic

The Wilcoxon test for independent samples (bilateral contrast) proves that, before the pandemic, there were hardly any significant differences by gender in the frequencies of ICT use among Engineering professors (Table 14). In Science professors, there were only differences in the use of evaluation tools, more frequently used by males (W = 1287.5; p-value = 0.0053) and in Health Sciences only gender differences were observed in the use of ICT during classes, also more frequently used by males (W = 1458.0; p-value = 0.0060). However, gender gaps have increased after the pandemic, mainly among Science and Engineering professors (Table 15). Among the former, females more commonly use presentations for class (W = 572.0; p-value = 0.0003) and digital tools to hold meetings (W = 717.5; p-value = 0.0257) than males. Among Engineering professors, females employ more presentations for class (W = 2148.0; p-value = 0.0124) and evaluation tools (W = 2182.0; p-value = 0.0290). Male Health Sciences professors use digital evaluation tools more frequently than female ones after the pandemic (W = 1372.5; p-value = 0.0343).

The results confirm that, before the pandemic, there were some digital age gaps in the frequency of use of certain tools (Table 16). In Sciences, before the pandemic, a moderate negative influence of age is observed in the use of presentations for class (S = 168048; p-value = 0.0002), in Health Sciences the same occurs with the use of presentations (S = 203046; p-value = 0.0002) and other ICT resources for the conduct of lessons (S = 191975; p-value = 0.0028). In Engineering, something analogous occurs with the use of digital media to hold meetings (S = 485613; p-value = 0.0119). However, the increase in the use of digital tools derived from the pandemic has caused all these digital gaps to be corrected, so that age does not significantly influence the use of any of the tools in the post-COVID period in any of the knowledge areas studied (Table 16).

	Science		Health Sci.		Engineering	
ICT tools	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
Presentations for class	3.86	4.11	3.69	3.58	3.88	4.00
ICT tools for class use	3.11	3.15	3.38*	2.63*	3.18	3.30
Meetings with the staff	3.40	3.00	2.62	2.42	2.96	3.26
Tutorials with students	3.11	2.87	2.54	2.58	2.92	2.96
Content sharing tools	3.91	3.64	3.23	3.00	3.62	3.67
Evaluation tools	3.63*	2.89*	2.62	2.21	2.96	2.96

Table 14. Average frequencies in each area of knowledge before the pandemic, differentiated by gender (*$p<0.05$ in the bilateral Wilcoxon test for independent samples)

	Science		Health Sci.		Engineering	
ICT tools	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
Presentations for class	3.94*	4.56*	4.54	4.32	4.44*	4.78*
ICT tools for class use	4.23	4.47	4.62	4.47	4.44	4.63
Meetings with the staff	4.11*	4.47*	4.00	4.16	4.40	4.67
Tutorials with students	3.83	4.04	3.77	4.05	4.20	4.37
Content sharing tools	4.23	4.51	4.54	4.32	4.54	4.74
Evaluation tools	4.14	4.27	4.46*	4.05*	4.22*	4.59*

Table 15. Average frequencies in each area of knowledge after the pandemic, differentiated by gender (*$p<0.05$ in the bilateral Wilcoxon test for independent samples)

	Sciences		Health Sci.		Engineering	
ICT tools	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Presentations for class	–0.3833*	–0.1828	–0.3771*	–0.1881	0.1192	–0.0350
ICT tools for class use	–0.0311	–0.0274	–0.3021*	0.0739	0.0777	–0.0920
Meetings with the staff	–0.1557	–0.1623	–0.0242	0.1871	0.2022*	–0.0597
Tutorials with students	–0.0172	–0.0475	0.0638	0.0024	0.1194	–0.0011
Content sharing tools	–0.1828	–0.1637	–0.1292	–0.0881	0.0844	–0.1308
Evaluation tools	–0.2042	–0.1086	–0.0505	–0.0650	0.0829	0.0003

Table 16. Spearman correlation coefficients of the frequencies of use of ICT tools in each area with respect to the age variable. “Pre” means pre-pandemic and “Post” means post-pandemic (*$p < 0.05$ in the Spearman correlation test)

5. Discussion

Science and Technology professors give high ratings to ICT didactic resources, regardless of the specific area (Table 8). These results are in line with other studies which confirm that methodologies based on the use of ICT help to increase the academic performance and the development of the competences of university students of any degree, in the opinion of the professors (Liesa-Orús et al., 2020). The literature reveals that the geographic factor does not have a significant influence in this regard, so that good ratings are found among Latin American faculty in a similar way to those of other regions (Antón-Sancho et al., 2021b). However, the self-concept about their own digital skills is intermediate, especially in terms of their techno-pedagogical skills, that is, their ability to apply ICT didactically. This observation is in line with the previous literature, which usually finds a deficit in the digital competence of professors (Garzón-Artacho et al., 2021; Tsegay et al., 2022; Yáñez-de-Aldecoa & Gómez-Trgueros, 2022). It also agrees with the opinion of the students, who value the digital skills of professors as improvable (Gómez-Poyato et al., 2022).

On the other hand, the assessment of digital competence is intermediate, and the training received on ICT is considered insufficient by professors (Table 8). As schematically presented in Figure 5, the valuations of Engineering professors are better than those of professors in the other areas, which probably derives from their greater experience with the use of technology (Table 9). This reveals the importance for universities to increase the amount and frequency of their training in the didactic use of ICT. Previous work supports the effectiveness of this type of training (Cubeles & Riu, 2018; Cabero-Almenara et al., 2020; Aquino et al., 2021; Cored-Bandrés et al., 2021; Santo et al., 2022). It would also be advisable that these trainings are specifically focused on the integration of ICT in teaching and learning processes and that the approach to the use of ICT prioritizes their didactic and pedagogical application (Montoro et al., 2015). It is probably also useful to focus on the digital competence of professors in each country to design their training, given that there are indeed differences in this regard (Iomäki, 2011; Basantes-Andrade, 2020; Fernández-Arias et al., 2021). In addition, following the results obtained in the present research, the above training should address the specific needs of professors in each knowledge area, in terms of previous training and adequacy to the learning objectives of each field. Training sessions should also be especially frequent or intensive among Sciences and Health Sciences professors, since they report being less familiar with ICT than Engineering professors (Table 9). Formal regulation of the use of virtual environments and digital tools by universities would help to strengthen the use of ICT resources among professors (Contreras et al., 2021).

There are other contextual factors that may explain the low ratings of digital competence and training received in the specific geographical zone of Latin America. Specifically, it is worth highlighting the access of professors to the necessary technological resources and their availability in universities (Cinotti et al., 2018; Rodríguez-Abitia et al., 2020; Hordat & Hayness-Brown, 2021). The specialized literature states that these requirements –particularly, in terms of access to the Internet and information technologies– are especially important in the field of Health Sciences (Cassiani et al., 2017), which could explain the low ratings in this regard obtained in this work. There could also be some influence of digital stress caused by the pandemic in the perceptions expressed by professors (Rangel-Pérez et al., 2021; Vergara-Rodríguez et al., 2022). In higher education, the use of mobile devices by professors could be probably an economically viable and sustainable alternative to correct some problems of access to technological resources (Marín-Raventós & Calderón-Campos, 2016).

Regarding the impact of the COVID-19 pandemic on the habit of using ICT, this has increased after the pandemic in all teaching activities (Figure 3). This is in line with what has been proved in previous works (Vergara-Rodríguez et al., 2022). As summarized in Figure 5, Health Sciences is the knowledge area in which the increase has been greatest, followed by Engineering and, finally, Science (Figure 4). This is in line with the high capacity for adaptation that the literature attributes to Latin American university faculty, especially those in the studied knowledge areas (Antón-Sancho, 2022a). Latin American Health Science students have been classically reluctant to incorporate ICT resources (Muñoz-Cano et al., 2012), which is consistent with the fact that the greatest increase is found in this area. Indeed, the digitization needs derived from the pandemic have forced Heath Sciences professors to integrate ICT into teaching-learning activities until their use is higher, in some teaching activities, to that of the rest of the areas studied in this work (Table 13). The use of ICT resources by professors has been the subject of interest in previous literature, but with the main purpose of assessing the use of different media, such as laptops, apps, or social networks (Ricardo-Barreto et al., 2020), instead of the different didactic activities. Nor have any studies been found that assess the impact of the pandemic on these usage habits, so these results are novel in this regard.

Some gender gaps were found in the digital competence ratings of Science and Health Sciences professors, but not in Engineering (Table 10), as it is represented in Figure 6. Specifically, female Science professors express less knowledge about ICT than males and male Health Sciences professors know less ICT terminology than females, although females are more willing than males to increase their training. These results show that a digital gender gap persists among Latin American faculty, at least in the areas of Science and Health Sciences, and that female professors are working to correct these differences, which is in line with previous literature (Iomäki, 2011; Basantes-Andrade, 2020; Palomares-Ruiz, 2020; Ramírez-Lozano et al., 2022).

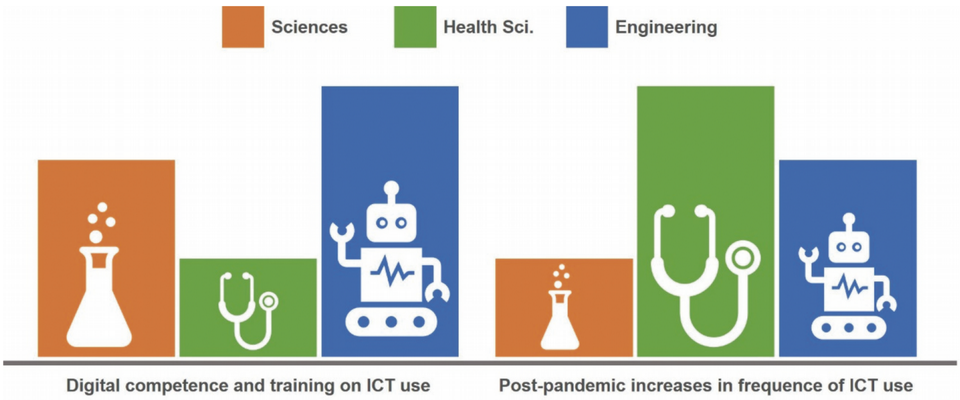

Figure 5. Diagram of the results on digital competence and training received in the use of ICT and on the increase in ICT use caused by the pandemic

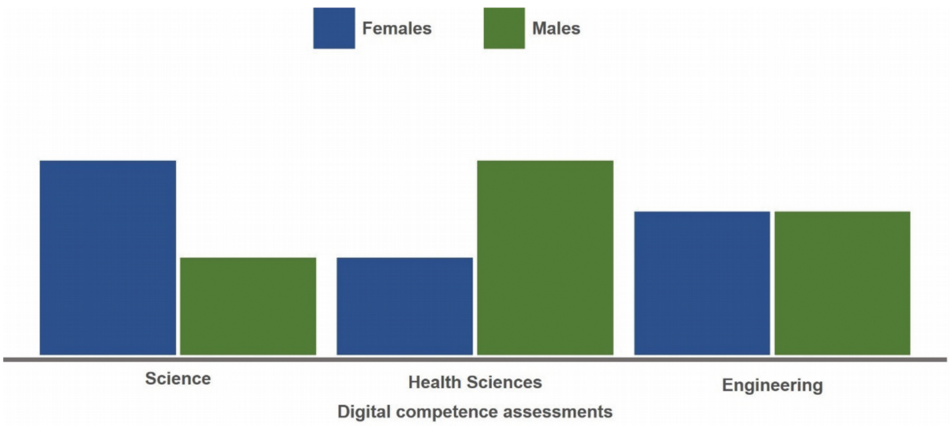

Figure 6. Diagram of the results on digital competence in each of the knowledge areas analyzed, differentiated by gender

The absence of gender gaps in the opinions of Engineering professors had already been pointed out by the preceding literature as a specific phenomenon of technical education faculty in Latin America (Basantes-Andrade et al., 2020; García-Holgado et al., 2020). Other studies, also contextualized in Latin American university professors, have found gender differences in digital competence that favor females (Antón-Sancho et al., 2022b). These results contrast with those obtained in analogous studies, but with students, carried out in other regions, which present clear gender gaps favoring males in Engineering (Peña et al., 2022). They also contrast with the low rate of females' access to higher degrees in science and technology in Latin America (Contreras-Ortiz, 2020; Holanda & Da-Silva, 2022).

As discussed in the results section, the COVID-19 pandemic has led to an increase in the gender gap in the frequency of didactic use of ICT in the three analyzed knowledge areas (Tables 11 and 12). The scientific literature had already pointed out that the pandemic has caused a certain widening of the gender gap in different aspects that affect the work of university professors (Peña et al., 2022). In Science, the pandemic causes females to use ICT tools more than males for presentations in class and meetings. In Engineering, something similar occurs with tools for presentations and evaluations. In Health Sciences, on the other hand, the pandemic causes males to use evaluation tools more than females. Consequently, it can be stated that in Science and Engineering the pandemic has strengthened the role of females in the use of digital resources in the university, but this effect has not occurred in Health Sciences, as shown in Figure 7. This novel and original result of the present study encourages further analysis of the specific case of Health Sciences to identify the underlying reasons why this area differs from the rest of the scientific-technical fields.

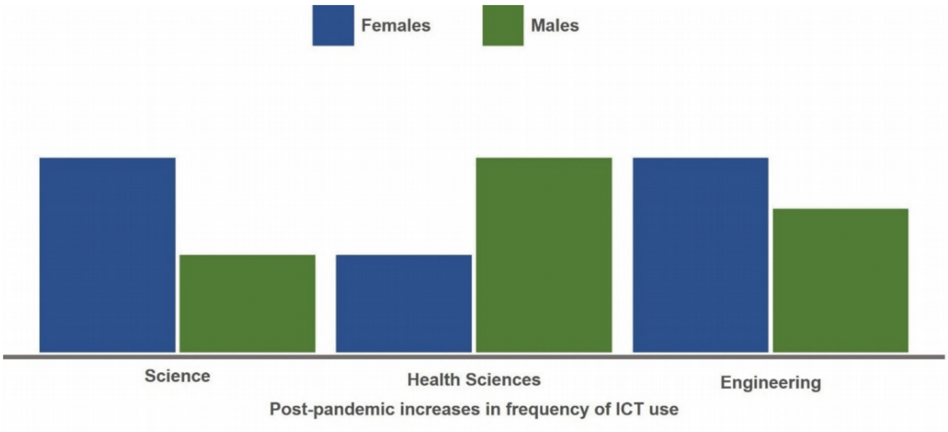

Figure 7. Diagram of the increase in the use of ICT tools in higher education in each of the three areas of knowledge studied, when differentiated by gender

The suggestion that has been made about increasing the digital training of professors in an economically sustainable way and attending to the specificities of the area of knowledge and the practical didactic application, should also aim to try to correct the gender gap that has arisen during the pandemic. To this end, universities should promote the implementation of virtual and telematic learning environments that, while encouraging the didactic use of ICT, favor the family conciliation (Marín-Raventós & Calderón-Campos, 2016).

Among Engineering professors, no significant digital age gaps were identified in digital competence or in their assessment of ICT (Table 11). Other studies have already pointed out the absence of an age gap in the digital competence of Latin American Engineering professors (Vergara et al., 2022a). Among Science and Health Sciences professors, a certain influence of age is identified, mainly in the assessment of ICT training received and in the knowledge of specific terminology, which decreases with age. These results are in line with the generational gaps that the literature reports regarding the digital competence of faculty (Basantes-Andrade et al., 2020; Cabero-Almenara et al., 2021; Antón-Sancho et al., 2022b). Regarding the frequency of use of ICT teaching resources, a certain digital age gap was found in the three areas before the pandemic, so that the habit of using certain tools decreased with age (Table 16). These gaps have been corrected after the pandemic. Therefore, it can be concluded that: (i) the digital age gap affects differently the frequency of use of the different tools according to the area of knowledge –tools to dynamize the class in Sciences and Health Sciences and for meetings in Engineering–; and (ii) the needs for digitalization of the training processes derived from the pandemic have caused these digital gaps to be corrected.

From this work, some lines of future research are opened. Among them: (i) to carry out a comparative and correlational analysis of the impact of the pandemic on the habit of educational use of ICT in the different countries of the Latin American and Caribbean region and of this with other regions –for which it would be necessary to increase the size of the sample–; (ii) to identify the sociological, cultural or academic factors that explain the appearance of gender gaps in the use of ICT after the pandemic and that these gaps behave differently in the various scientific-technical areas; (iii) to check whether the support device of the different digital teaching tools –computer, app, social networks– or the technological needs re (ii) The self-perception of digital competence of Health Sciences professors is worse than that of their Science and Engineering colleagues.quired for their use –camera, sound device, specific software with license for use– influence the habit of their use by science and engineering professors; and (iv) to design and carry out a training course on the use of different ICT for teaching purposes and analyze its impact on the ICT usage habits of the professors involved.

6. Conclusions

Throughout the work, the following results have been shown: (i) the participating Science, Health, and Engineering professors give intermediate assessments to their digital competence, their skills to didactically apply ICT during their lectures being especially low; (ii) the self-perception of digital competence of Health Sciences professors is worse than that of their Science and Engineering colleagues; (iii) among both Health Sciences and Science professors, females show better digital skills than males, while among Engineering professors there is no significant gender gap in terms of digital competence; (iv) the COVID-19 pandemic has caused an increase in the frequency of use of ICT in lectures in all didactic activities, but this increase has been carried out unevenly in the areas of Science, Health and Engineering, and between genres within each area of knowledge.

The participating Science and Technology professors report having an intermediate level of digital skills. Within this digital competence, technical knowledge of ICT and specific terminology are the aspects in which they show the greatest ability, while the assessment of their techno-pedagogical skills is lower. Likewise, they understand that it is necessary that, within the scope of their university centers, teacher training be increased in terms of didactic skills for the use of ICTs. In this sense, Engineering professors assess both their digital competence and their training better than those in Science or Health Sciences. The valuations of the academic aspects of ICT use are very high, with no significant differences between the three areas analyzed in this respect.

The pandemic has led to an increase in the habit of using ICT tools in all teaching activities. This increase is higher among Health Sciences professors than in the rest of the disciplines. In addition, after the pandemic it is observed that there are some gender gaps in the frequency of use of some ICT tools that did not exist before the pandemic. In general, these gaps indicate that there is a more frequent use of these tools by females than males and are mainly found among Science and Engineering professors. In addition, the increase in ICT use caused by the pandemic seems to have corrected some digital age gaps that existed in the frequency of ICT use for some teaching activities, especially in Health Sciences.

For future research, it is proposed to apply the survey designed and validated here to a sample of professors distributed homogeneously by areas of knowledge and gender, as well as to identify other sociological or academic variables that may play a role in explaining the differences in the digital competence of teachers and in their ICT use habits. In this way, the results obtained in the present study could be contrasted. The specific geographical location of the participants limits the possibility of generalizing the results obtained, so it is proposed to extend the sample to other geographical areas. With this, it will also be possible to confirm whether the geographical factor is significantly influential with respect to the variables analyzed. Finally, it is proposed, as future lines of research, to complete this study with a qualitative analysis that helps identify the reasons for the gaps due to gender and area of knowledge identified here in terms of digital competence and the impact of the pandemic in the frequency of ICT use.

It is recommended that universities increase the frequency of training activities on the digital competence of teaching staff and that this training should address the specific needs of each area of knowledge. In addition, governments and universities should increase investment in equipment and technologies to be able to effectively incorporate ICT in teaching. In this regard, it would be advisable to think about technological alternatives that are economically viable and sustainable, such as mobile devices. This type of technology would also facilitate the reconciliation of family life with teaching and the institutionalization of virtual learning environments, which could help to correct the gender gaps generated after the pandemic.

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