frontiers | Frontiers in Computer Science

TYPE Original Research
PUBLISHED 30 July 2025
DOI 10.3389/fcomp.2025.1611952

OPEN ACCESS

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RECEIVED 15 April 2025
ACCEPTED 11 July 2025
PUBLISHED 30 July 2025

CITATION
Aquino J, Alarcón R, Guevara L, Bravo-Jaico J, Germán N, Valdivia-Salazar C, Serquén O, Maquen-Niño GLE and Tesén-Arroyo A (2025) Impact of digital transformation: assessing the knowledge and adoption of disruptive technologies in a higher education institution. *Front. Comput. Sci.* 7:1611952. doi: 10.3389/fcomp.2025.1611952

Impact of digital transformation: assessing the knowledge and adoption of disruptive technologies in a higher education institution

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Digital transformation has become a key factor for educational development since it not only involves the integration of disruptive technologies but also the restructuring of the process and cultural adaptation that allows Higher Education Institutions (HEI) to respond to changes in society and the demands of the labor market. This article aimed to determine the level of knowledge about the different aspects of digital transformation in a HEI, encourage the adoption of disruptive technologies and facilitate an effective transition to digital educational environments through an analysis based on 6 dimensions such as: important principles and definitions, technological support for DT, Digital tools, disruptive technologies in DT, Security in Information Technologies and Digital Culture, applying two surveys as instruments to teachers, students and graduates of the university community. A quantitative approach with quasi-experimental design was used, evaluating a pre-test and post-test with a total of 34 questions distributed among the six dimensions analyzed using a Likert scale and applying the Wilcoxon statistical test for related samples. The initial findings indicate that in the first dimension "important principles and definitions" with 6 questions, two of them do not present adequate significance with values of 0.06505 and 0.051, respectively. On the other hand, the dimensions technological support (6 questions), Disruptive technologies (9 questions), Digital tools (6 questions) and Information Technology Security (ICTs; 4 questions), obtained significant results in each of their questions, finally the Digital Culture dimension (4 questions) presents a question with a p-value of 0.24 presenting no significant difference, that is, the answers of the participants did not vary. In addition, at the dimension level, the one that shows the best results is Disruptive Technologies with a p-value of 9.08×10^{-17}, which indicates that after the training, significant improvements were obtained in this dimension as opposed to the rest. Finally, performing the global analysis of the dimensions in terms of gender the scores in women are higher with respect to men, in addition, considering the analysis based on roles it was determined that teachers show better results and students have lower scores.

KEYWORDS

digital transformation, disruptive technologies, knowledge, higher education institution, technology adoption

1 Introduction

In recent years, higher education has undergone a profound transformation driven by digitization, especially accelerated by the COVID-19 pandemic, giving rise to Digital Transformation (DT) which, driven by the Fourth Industrial Revolution, impacts sustainability (Trevisan et al., 2024) and open knowledge in higher education (Shenkoya and Kim, 2023), from this context, information and communication technologies (ICT) have played an important role in this process, facilitating new teaching and learning modalities, generating important changes in education and offering opportunities to introduce new educational methods and strategies (Arkhipova et al., 2024).

To achieve DT, a cultural change is necessary, that is, transforming the organizational culture to adopt a digital mindset (Díaz-García et al., 2023), since digital technology has become necessary to develop daily activities, so its presence in the contemporary world is a necessity (Jabborova et al., 2024), therefore, globalization requires the existence of specialists with technological knowledge to stimulate DT in the educational industry (Liu, 2024).

The modernization of universities through DT, allows them to be more efficient and respond faster to the demands of today's society (Castañeda et al., 2023), furthermore, DT contributes to educational management in the internet era (Li, 2024), as well as to the quality of service in the educational sector (Aisyah et al., 2023).

Higher education institutions (HEIs) have an important role in the development of the United Nations 2030 Agenda to address the Sustainable Development Goals (SDGs), thus, DT is seen as a means to achieve such agenda (Trevisan et al., 2024); adopting this type of international practices can help universities to provide effective mechanisms to fulfill their responsibilities, thus contributing to Vision 2030 (Alenezi and Akour, 2023).

There is a need to transform the education system to prepare students with digital competencies in response to increasing global digitization and the demands of the labor market (Narkoziev et al., 2024), so educational interventions that leverage digital technology to adapt to the individual characteristics of students (Liu and Zhou, 2024), generating an educational ecosystem as a comprehensive approach to connect technological and educational resources to create a cohesive learning experience (Polyakova, 2023), investing in technological infrastructure and continuous training programs for staff to ensure the effectiveness of DT (González Garcés et al., 2024).

Universities must adapt their teaching methods, curricula and instructional programs to respond to the changing needs of society driven by the rapid DT of industries and social systems (Chodzko, 2023), however, HEIs face challenges in trying to implement comprehensive and sustainable DT, among these challenges are the integration of digital technologies, protection of personal data, investment in technological infrastructure (Alenezi and Akour, 2023), thus evidencing the need to adapt HEIs to the changes and demands of the labor market in the era of Industry 4.0, ensuring that students acquire the necessary digital and professional skills (Dimitrova and Marinova, 2024).

The resistance of HEIs is reflected in the barriers and challenges faced by institutions and staff in adopting new technologies (Díaz-García et al., 2023), managing changes in workforce, technology and culture to facilitate DT (Peeters et al., 2023) because this is not a linear process and many challenges are encountered along the way (Laterza et al., 2023) that hinder effective university-industry collaboration for DT and innovation; some of these barriers are limited resources, lack of capabilities and university support (Evans and Miklosik, 2023).

The COVID-19 pandemic has accelerated digitization (Laterza et al., 2023) and organizational resilience (González Garcés et al., 2024) especially within HEIs (Wollscheid et al., 2023). From this context, DT has maintained educational continuity with the aim of improving the accessibility and flexibility of learning, preparing the student for digitized environments (Amer jid Almahri et al., 2024), through the adoption of emerging technologies such as machine learning, STEM education, smart tutoring, etc. (Deroncele-Acosta et al., 2023), however, digital divides, informational and access inequality (Sydorenko et al., 2024), and lack of strategic support may hinder the efforts of HEIs (Panteli, 2024).

DT in higher education has become a necessity for the modern era (Li, 2024), whereby the adoption of digital technologies generates a value proposition of digitized educational and operational models (Gkrimpizi et al., 2024); thus, its implementation implies the restructuring of all areas of activity of an organization, where ICTs are fundamental to carry out specialized programs and individualized learning trajectories (Novikov and Sazonov, 2024), integrating human-centricity, sustainability and resilience (Osorio et al., 2024), where digital learning facilitates education (Issakov et al., 2023).

DT in HEIs rethinks the educational process where communication between teachers and students, as well as teaching and evaluation methods are supported through digital platforms and technologies in order to improve the quality of learning and digital literacy (Dimitrova and Marinova, 2024), for this process specific roles are identified: teachers, students, educational developers and administrative staff (Scholkmann, 2023). Teachers in the DT process, are an important axis to overcome digital challenges (Bisri et al., 2023), however, there are problems related to teachers in the context of digital learning systems, as the adaptation process is not optimal generating little effective use of technologies (Jabborova et al., 2024) despite the fact that they tried to use different innovative methods to provide educational continuity (Alvarado-Acosta et al., 2024).

HEIs and industry must collaborate to promote knowledge sharing and drive innovation and thus, integrate effective digital practices that lead to competitive advantage (Evans and Miklosik, 2023), the importance of DT in this collaborative scenario, lies in its ability to improve operational efficiency, enhance educational quality, improve the student and staff experience, and increase the competitiveness of universities, being seen as a necessity for HEIs to remain relevant in an increasingly competitive and technologically advanced global educational environment (Farias-Gaytan et al., 2023).

The issue of DT in HEIs focuses on the promotion of learning through collaborative educational experiences, as well as on the development of teamwork skills using roles and developing academic

competencies (Ilhan-Nas et al., 2024). This has generated digital divides that, according to Sydorenko et al. (2024) could be closed by creating a cohesive information and communication ecosystem that integrates technological, scientific and educational resources, as well as hardware, software, support policies and technological platforms (Thong and Ngoc, 2023). DT represents a strategic challenge to update traditional university functions (Gaete Quezada, 2023); however, there is still a lack of a comprehensive approach to guide the implementation of DT at the university level (Castañeda et al., 2023).

For Peruvian education, DT after the COVID-19 pandemic has taken a remarkable boost (Alvarado-Acosta et al., 2024), so institutions have had to adopt digital tools to continue with their academic and administrative activities (Wong-Galvez and Libaque-Saenz, 2023), to achieve this, there was financial support that impacted positively on the DT index of universities.

In order to achieve an effective adaptation to DT, the challenges and strategies aimed at students, teachers and institutions must be identified, in this way, HEIs will be able to maintain their competitiveness in the digital environment (Budiyanto et al., 2024). However, the current situation is different, since many of these institutions do not understand this process despite its importance in the educational field.

The lack of familiarity with the basic concepts, instruments and methods of DT generates important obstacles when seeking to incorporate new technologies in teaching, this situation causes some institutions to adopt digital tools irregularly while others remain in the context of traditional systems that no longer meet the needs of education.

Therefore, this study aims to answer the following research questions:

1. What is the level of knowledge of the university community about the fundamental concepts of digital transformation in an HEI?
2. How familiar are students and faculty with the key principles and definitions of digital transformation in the university context?
3. What is the level of knowledge about the technological infrastructures that support digital transformation in a public university?
4. How well do members of the university community understand the digital tools that facilitate teaching and learning in a digital environment?
5. To what extent are disruptive technologies known within the public university?
6. What is the level of knowledge about IT security practices among students, faculty and alumni of the university?
7. How is digital culture perceived in the context of digital transformation within the public university?

Students, teachers and graduates should have an adequate level of knowledge about DT, to improve the efficiency and effectiveness of academic-administrative processes. In this context, the objective of this study is to determine the level of knowledge about the different aspects of digital transformation in a HEI, to encourage the adoption of disruptive technologies and to facilitate an effective transition to digital educational environments.

2 Theoretical framework

2.1 Important principles and definitions

DT is a process of adopting disruptive technologies that increases productivity, value creation and social welfare (Scholkmann et al., 2024), integrating digital competencies and advanced technologies in open innovation processes, ranging from basic digitalization to the implementation of artificial intelligence and its relationship with sustainability (Espina-Romero et al., 2024); this process is broad and organizational change involving the adoption of digital technologies, creating disruptions for organizations to respond strategically to changes (Wollscheid et al., 2023).

In today's education, DT seeks to make teaching optimal by using digital tools throughout the learning process (Dimitrova and Marinova, 2024). It also allows the use of technologies such as machine learning and data analysis, which help each student learn according to what they need (Liu and Zhou, 2024), therefore, it is important that universities are at the forefront with technology, as it impacts both the administrative and academic part (Castañeda et al., 2023). When talking about DT, it also refers to issues such as digitization, the use of technology and digital skills.

Digitalization at the higher education level implies significant changes in how assessments are conducted, where teachers must modify their methods to take advantage of digital tools, however, this process reveals limitations in technical knowledge (Barman and Weurlander, 2023). The incorporation of digital tools in education began in the 1990s with the development of learning management systems (LMS) and educational platforms (Øvrelid et al., 2023). This integration has transformed higher education by incorporating advanced methods and reducing the gap between face-to-face and virtual teaching, which, today, universities need to offer these educational experiences for greater reach and effectiveness (Rosak-Szyrocka, 2024).

Digital maturity assesses the extent to which an institution is prepared to adopt and manage digital technologies (Scholkmann et al., 2024); its models are used to assess the DT capability of organizations. They include dimensions such as digital strategy, leadership and culture, market digitization, strengthened logistics, and dynamic and digital capabilities (Wong-Galvez and Libaque-Saenz, 2023).

Digital literacy refers to the knowledge and skills needed to use digital technologies (Narkoziev et al., 2024).

Digital competencies are skills and knowledge necessary to effectively navigate in the digital environment (Espina-Romero et al., 2024) and interact effectively with advanced technologies (Osorio et al., 2024). Pinheiro et al. (2023) defines them as the set of knowledge, skills, attitudes, strategies and awareness necessary to use digital technologies effectively and ethically.

In the educational context, digital competence is the ability of students and staff to use digital technologies effectively (Li, 2024), these enable successful DT, which in turn improves the quality of service in higher education (Aisyah et al., 2023). The digital competence of teaching staff allows them to take full advantage of digital learning spaces (Tømte et al., 2023).

Innovation is the ability to create new products and services, improving internal processes through the use of digital technologies (Wong-Galvez and Libaque-Saenz, 2023). Open innovation refers to

collaborative processes that integrate external and internal knowledge to innovate (Espina-Romero et al., 2024), where companies, including HEIs, acquire knowledge from external sources (Evans and Miklosik, 2023). Pedagogical innovation is the adaptation of teaching and learning methods to integrate digital technologies and improve educational quality (Laterza et al., 2023).

All these concepts give rise to universities 4.0 and 5.0, refers to the evolution of universities towards fully digital models that integrate sustainability and emotional competencies (Rosak-Szyrocka, 2024), advocate the modernization of educational activities to meet the requirements of Industry 4.0 (Ilhan-Nas et al., 2024; Thong and Ngoc, 2023).

Finally, digital transformation prepares students for the digitized labor market and for ensuring the quality and relevance of the educational system (Narkoziev et al., 2024), improving the efficiency and effectiveness of HEIs, enabling greater innovation, competitiveness and responsiveness to market and societal demands (Evans and Miklosik, 2023), personalizing learning, accessibility and preparation of students for a digitized labor market (Barman and Weurlander, 2023), thus, the importance of digital transformation in higher education is an essential response to the demands of Industry 4.0 (Ilhan-Nas et al., 2024).

2.2 Technological support for DT in higher education

Technology at university makes studying easier and more adaptable (Issakov et al., 2023) allowing students to use the tools they need to study online (Zarubina et al., 2024). This includes having computers and good internet connection, so that everyone can study online with the same opportunities (Hamdanah et al., 2024). It also helps to make education better and allows using new ways of teaching that improve professional skills, making everyone learn in their own way and achieve good results, as Aksyonov et al. (2021) say in their study on how to innovate in education.

Virtual learning environments (VLE) allow students to study asynchronously (Zarubina et al., 2024), adapting the study according to their time and what they need (Hamdanah et al., 2024). Therefore, Issakov et al. (2023) state that in these digital spaces one can find the necessary resources for learning.

Social networks have become important for studying online, because they serve to converse and share information, making it easier for students and teachers to communicate and work together, forming digital groups to learn (Aksyonov et al., 2021). About this, Fuentes Cancell et al. (2021) say that universities should use social networks for students to interact and learn in groups, so they should be used in an orderly way to learn better. Therefore, digital channels boost e-learning, helping universities to be more digital (Hamdanah et al., 2024).

2.3 Digital tools

Digital tools are part of virtual study and allow finding materials to study and work collaboratively (Habib, 2023). Among these we have platforms for online study, applications for video calls and programs for teamwork that allow to have, for example, live classes (Eingartner et al., 2022). As explained by Fedajev et al. (2024), these tools make it easier to teach in virtual spaces, giving students and teachers what they need to share information and work together effectively.

Teamwork tools help students and teachers interact more on virtual platforms. As Mahsusi et al. (2024), in their study on digital education, they allow learning to be more participatory, making it easier to share resources and knowledge among everyone. Therefore, Hamdanah et al. (2024) mention that working collaboratively maintains team motivation.

Regarding research tools, OER (educational resources) and digital libraries allow access to academic material and help to create an environment where one learns by researching (Habib, 2023), these tools make education more research-based and allow finding new and useful information.

2.4 Disruptive DT technologies

Technologies that are changing the way of teaching, learning and using digital tools in Education 4.0, as stated by Dimitrova and Marinova (2024). About this, Gallastegui and Forradellas (2024) explain that technologies such as Artificial Intelligence (AI) are revolutionary because they can completely change how to teach and make each student learn in their own way. These tools are important to innovate and adapt when everything changes fast (Espina-Romero et al., 2024).

Industry 4.0 is a big challenge for universities, which now have to change their way of teaching and use new ideas for students to learn what companies need (Dimitrova and Marinova, 2024). Therefore, Fadlelmula and Qadhi (2024) state that it is important to use digital technology for education to improve and change the way of teaching according to what they are now asking for in the workplace.

Cloud computing, is the basis of DT in universities and is used to create small cloud services, these services make it easier to use programs to learn online, allowing educational resources to be used in a flexible way (Dimitrova and Marinova, 2024).

AI is changing the digital skills needed to work or study by helping to innovate and enabling new ways to interact and automate tasks in organizations (Espina-Romero et al., 2024). AI programs allow each student to learn better and have a better experience because they can see patterns that affect their satisfaction and progress in courses (Gallastegui and Forradellas, 2024).

2.5 Information technology security (IT security)

ICT security is a fundamental part of cybersecurity and is responsible for protecting the privacy of all information (Mohammed and Bamasoud, 2022), this is especially relevant now that digital technologies are converging in the era of Industry 4.0, where there is a need to protect both digital infrastructure and systems in an environment that is increasingly connected and digitized, as Gombár et al. (2024) point out in their analysis on digital security. ICT security measures allow maintaining data integrity in digital educational environments, including protection against intruders, maintaining confidentiality and ensuring that information stored in the cloud is not altered, as explained by Olifirov et al. (2023).

Cybersecurity is described as a set of controls and measures aimed at increasing awareness of cyber threats and risks, therefore, there is need to build a positive cybersecurity culture and in promoting responsible and aware behaviors among technology users (Mohammed and Bamasoud, 2022). In the digital age, it is a challenge that arises with the digitization of society and needs to be managed through digital literacy, critical thinking and responsible use of technology, this implies a need to protect information and communication systems in a rapidly changing digital environment; therefore, responsible use of technology should be encouraged, this suggests that, to properly navigate in the digital age, in addition to having technical knowledge and furthermore ethical approaches that considers the impact of technology on privacy (Padmanabhan, 2023).

2.6 Digital culture

Digital culture refers to the integration and effective use of digital tools and resources, in the context of higher education implies the need for university teachers to acquire adequate digital competencies to create digital resources, manage teaching-learning processes, evaluate students and empower them (Spain et al., 2024), from here arises the need to develop an organizational digital culture, which considers ICT infrastructure, content and information, research and innovation, communication, learning, teaching and evaluation (Wall et al., 2024).

In higher education it refers to how DT affects the educational environment, especially in universities and other higher education institutions, as education is transforming into a continuous process, reflecting the need for constant updating of knowledge and skills (Kirillova, 2023); it involves promoting digital skills, receptive attitudes towards technological innovation, and a general willingness to transform academic and administrative processes to align with new digital tools (Laorach and Tuamsuk, 2022).

3 Materials and methods

The research was developed under a quantitative and applied approach with a quasi-experimental design, since according to Hernández Sampieri and Mendoza Torres (2018) allows manipulating one of the independent variables to observe its effect on the dependent variables.

A pre-test was applied to a set of participants to identify basic knowledge about DT, then a training called Conference Cycle "An approach to digital transformation: Challenges and opportunities" was held from January 23 to 25, 2023 virtually, each topic lasted 3 synchronous hours and 4 asynchronous hours, making a total of 42 academic hours, where the following topics were addressed: Introduction to digital transformation, its objective was to familiarize participants with various digital tools that facilitate collaboration in digital environments; Disruptive technologies for DT, the objective was to explore the emerging technologies that are driving DT and understand their potential impact; Security in Information Technologies (ICT), the objective was to raise awareness about the importance of information security in digitalized environments and present strategies to protect data and systems; Technological Support for Digital Transformation in Higher Education Institutions. The objective was to analyze how infrastructure and technological support are crucial for implementing and sustaining digital transformation in higher education. Finally, the objective of the DT project was to understand the university's technological processes. In order to improve digital transformation knowledge, the entire process was completed with a post-test to evaluate these improvements.

The study evaluated the normality of the data obtained in both tests, applying the Kolmogorov–Smirnov test, which allowed us to determine whether the distributions differed significantly from a normal curve. Since the assumption of normality was not met, the nonparametric Wilcoxon test for related samples was used, which is suitable for evaluating changes in repeated measurements in the same sample. Likewise, the statistical significance test revealed significant differences between pre-test and post-test scores, which supports the hypothesis of improvement and justifies the validity of the study in the evaluation of the transformation obtained through the training conducted.

3.1 Participants

The study was applied to a total of 107 members of the administrative academic community consisting of our target audience of teachers, students, and graduates of a faculty at a national university, distributed among 22 teachers, 76 students, and 9 graduates. This sample was taken taking into account the participants who attended the training and also responded to the pre-test and post-test.

Table 1 provides a detailed analysis of the demographic characteristics of the participants in the study on the impact of digital transformation in higher education at a public university. Three key characteristics are highlighted: gender, role within the university

TABLE 1 Sociodemographic profile of the sample.

Variable	Value	*N*	Frequency (%)
Gender	Male	90	84.1
	Female	17	15.9
Role	Student	76	71.0
	Teacher	22	20.6
	Graduate	9	8.4
Academic Program	Computer Engineering and Informatics	43	40.2
	Electronics Engineering	37	34.6
	Mathematics	12	11.2
	Statistics	7	6.5
	Physics	5	4.7
Age Range	15–24	59	55.1
	25–34	24	22.4
	35–44	4	3.7
	45–54	10	9.3
	55–64	8	7.5
	65–74	2	1.9

(faculty, students and alumni) and academic program, in addition to a categorization of participants by age range.

In terms of gender, there was a marked male predominance, with 84.1% of the participants identifying themselves as men, compared to 15.9% of women. Regarding roles, students constitute the majority of the sample (71%), followed by teachers (20.6%) and a lower representation of graduates (8.4%). This data suggests that the student perspective predominates in the analysis of digital transformation.

The most represented academic programs are Computer Engineering (40.2%) and Electronic Engineering (34.6%), which is relevant considering that these disciplines are directly related to technology, which could bias the results towards a greater acceptance and knowledge of disruptive technologies. Finally, the participants are mostly distributed in the 15–24 age range (55.1%), indicating a young population, with a lower representation in higher age ranges. These data provide a crucial context for interpreting the study's findings and formulating strategic recommendations in line with the characteristics of the university population.

3.2 Instruments

Based on the literature review, two instruments were proposed and applied in two moments (pre- and post-test), consisting of 34 items, each one using a Likert scale with 5 options, where 1 means that they know nothing and 5 means that they know a lot about DT.

For the instrument, 6 dimensions were established, Principles and important definitions with 6 items where it is intended to measure the degree of knowledge of the key concepts of digital transformation, Technological support for DT in Higher Education with 5 items where its objective is to determine the knowledge of computer tools, computer systems that exist or that could be applied in HEIs, Digital tools with 6 items where it is intended to determine the degree of knowledge of collaborative, office automation, graphic design, research, learning and videoconferencing tools, Disruptive technologies of DT with 9 items where it is proposed to determine the degree of knowledge of the disruptive technologies that currently exist for the DT in organizations, Security in Information Technology (ICT) with 4 items where it is desired to know about the level of security in the application of ICT and the underlying ethical principles and finally the Digital culture with 4 items which will allow us to know the degree of digital culture and its commitment and identification in the process of digital transformation of the university.

It should be noted that the data were collected through self-reported surveys, which may be subject to biases such as social desirability or overestimation of one's own knowledge, in order to minimize possible biases in self-reported responses, methodological measures were adopted such as the application of surveys anonymously, the inclusion of clear and neutral instructions to avoid inducing responses, and the confidentiality of the data, these actions sought to reduce the effect of social desirability and overestimation of knowledge.

The surveys were consolidated into an online form for its application, adding to the survey sociodemographic questions such as age, gender, academic program and role, this instrument was shared with the participants using their institutional email account.

4 Results

4.1 Inferential statistics

For this research work, goodness-of-fit tests were applied to verify what type of distribution the data follow and therefore determine which test (parametric or non-parametric) to apply in the analysis of the data.

The Kolmogorov–Smirnov (K-S) test was established to evaluate the goodness of fit for the contrast of the normal distribution of the data, due to the data being greater than 50.

The results obtained from the normality test indicate that the data of the six dimensions evaluated do not follow a normal distribution. The p-values obtained are extremely low ($p < 0.05$), suggesting that there are significant differences between the distribution of the data and a theoretical normal distribution.

These results help us to understand that parametric tests would not be the most appropriate for the data set obtained. Instead, non-parametric approaches should be considered to ensure the validity of the conclusions drawn from these data so the "Wilcoxon test for related samples" will be applied.

4.2 Application of the Wilcoxon test for related samples for each of the dimensions

Table 2 presents the results of the analysis of the first dimension "Important principles and definitions" revealing significant differences in several of the questions between the pre-test and post-test. Specifically, questions A-PD-1, A-PD-3, A-PD-5 and A-PD-6 showed

TABLE 2 Results of the Wilcoxon test for the first dimension Important principles and definitions.

Pre test	Post test	Wilcoxon statistic	p_value
A-PD-1	D-PD-1	649.5	2.99E-07
A-PD-2	D-PD-2	1031.0	0.065058337
A-PD-3	D-PD-3	861.5	8.65E-05
A-PD-4	D-PD-4	1335.5	0.051104525
A-PD-5	D-PD-5	210.0	5.88E-14
A-PD-6	D-PD-6	197.0	2.91E-14

A-PD-1 to A-PD-6 refer to the 6 questions established in the instrument applied in the pre-test and D-PD-1 to D-PD-6 refer to the 6 questions established in the instrument applied in the post-test.

extremely low p-values (less than 0.001), indicating significant improvements in participants' scores after training. In contrast, questions A-PD-2 and A-PD-4 showed higher p-values (0.065 and 0.051, respectively), suggesting that, although there was an improvement, it was not statistically significant at the standard confidence level ($p < 0.05$). These results indicate that the training conducted had a positive impact on the understanding of most of the important principles and definitions related to this dimension.

Table 3 shows the analysis of the dimension "Technological support for DT in Higher Education" shows statistically significant results for all the questions evaluated. Questions A-ST-1, A-ST-2, A-ST-4 and A-ST-5 present extremely low p-values (less than 0.001), indicating a considerable improvement in the knowledge of technological support after the training conducted. Question A-ST-3 also shows a significant change with a p-value of 0.031, although the magnitude of the change is slightly less pronounced compared to the other questions. Finally, these results indicate a positive and widespread impact on the knowledge of technological support at the university, which could indicate progress in the integration and acceptance of disruptive technologies in the higher education environment.

Table 4 illustrates the analysis of the third dimension corresponding to Digital tools shows statistically significant differences between the pre-test and post-test results in all 6 questions evaluated. The results indicate significant improvements in the knowledge of digital tools post-training, with extremely low p-values, suggesting a generalized positive change. These results highlight the positive impact of the training on participants' ability to use digital tools in the context of higher education, which is crucial for effective digital transformation in this area.

Table 5 shows the analysis of the fourth dimension concerning Disruptive DT Technologies reveals statistically significant differences between the pre-test and post-test responses in the 9 questions

TABLE 3 Wilcoxon test results for the second dimension technological support for DT in higher education.

Pre_test	Post_test	Wilcoxon statistic	p_value
A-ST-1	D-ST-1	412.5	5.05E-12
A-ST-2	D-ST-2	399.5	1.60E-12
A-ST-3	D-ST-3	1192.0	0.031164307
A-ST-4	D-ST-4	584.0	2.96E-10
A-ST-5	D-ST-5	730.0	1.45E-07

A-ST-1 to A-ST-5 refer to the 5 questions established in the instrument applied in the pre-test and D-ST-1 to D-ST-5 refer to the 5 questions established in the instrument applied in the post-test.

TABLE 4 Results of the Wilcoxon test for the third dimension digital tools.

Pre_test	Post_test	Wilcoxon statistic	p_value
A-HD-1	D-HD-1	903.0	0.000932951
A-HD-2	D-HD-2	937.0	9.05E-05
A-HD-3	D-HD-3	564.5	2.29E-07
A-HD-4	D-HD-4	262.5	2.68E-11
A-HD-5	D-HD-5	612.0	4.88E-06
A-HD-6	D-HD-6	768.0	0.006290547

A-HD-1 to A-HD-6 refer to the 6 questions established in the instrument applied in the pre-test and D-HD-1 to D-HD-6 refer to the 6 questions established in the instrument applied in the post-test.

TABLE 5 Results of the Wilcoxon test for the fourth dimension disruptive technologies of DT.

Pre_test	Post_test	Wilcoxon statistic	p_value
A-TD-1	D-TD-1	214.0	3.20E-13
A-TD-2	D-TD-2	328.5	9.62E-13
A-TD-3	D-TD-3	348.5	1.58E-10
A-TD-4	D-TD-4	30.0	7.52E-16
A-TD-5	D-TD-5	291.5	7.31E-11
A-TD-6	D-TD-6	283.0	9.42E-12
A-TD-7	D-TD-7	259.0	1.45E-12
A-TD-8	D-TD-8	221.5	6.00E-13
A-TD-9	D-TD-9	120.5	2.07E-14

A-TD-1 to A-TD-9 refer to the 9 questions established in the instrument applied in the pre-test and D-HD-1 to D-TD-9 refer to the 9 questions established in the instrument applied in the post-test.

TABLE 6 Results of the Wilcoxon test for the fifth dimension information technology security (ICT).

Pre test	Post test	Wilcoxon statistic	*p*_value
A-ST-1_1	D-ST-1_1	224.0	7.03E-14
A-ST-2_2	D-ST-2_2	224.0	2.47E-13
A-ST-3_3	D-ST-3_3	515.0	9.43E-08
A-ST-4_4	D-ST-4_4	388.0	1.19E-10

A-ST-1 to A-ST-4 refer to the 4 questions established in the instrument applied in the pre-test and D-ST-1 to D-ST-4 refer to the 4 questions established in the instrument applied in the post-test.

TABLE 7 Results of the Wilcoxon test for the sixth dimension digital culture.

Pre test	Post test	Wilcoxon statistic	*p*_value
A-CD-1	D-CD-1	407.0	5.560716598457979e-11
A-CD-2	D-CD-2	340.0	4.337462848405344e-13
A-CD-3	D-CD-3	492.0	4.237776815769088e-11
A-CD-4	D-CD-4	1022.5	0.24980834992255418

A-CD-1 to A-CD-4 refer to the 4 questions established in the instrument applied in the pre-test and D-CD-1 to D-CD-4 refer to the 4 questions established in the instrument applied in the post-test.

evaluated. The *p*-values obtained are very low, indicating significant improvements in this dimension. This suggests that the training has been highly effective and has allowed to increase the knowledge of disruptive technologies among the participants.

Table 6 presents the analysis of the fifth dimension referring to Information Technology Security (ICT) showing statistically significant differences between the pretest and post-test responses in the 4 questions evaluated. The *p*-values are very low indicating significant improvements in the responses on ICT security after the training conducted at the institution. These results suggest that the training has been effective in increasing knowledge about IT security among the participants, a very important aspect for secure digital transformation within the higher education environment.

And Table 7 presents the analysis of the sixth dimension Digital Culture reveals significant differences between pretest and posttest in three of the four questions evaluated. Extremely low significance for questions A-CD-1, A-CD-2 and A-CD-3 indicate significant improvements in digital culture after training. However, question A-CD-4 does not show a significant difference ($p = 0.249$), suggesting that in this specific aspect there was no statistically relevant change. Finally, these results indicate a general improvement in the digital culture of the participants, although with some aspects that may require additional attention.

4.3 Impact of the training provided to participants

The *p*-values obtained were compared between the different dimensions evaluated. The results show that, in almost all dimensions, the *p*-values are quite low, indicating statistically significant improvements in each of the dimensions analyzed after the training given to the participants.

The DT Disruptive Technologies dimension that showed the greatest improvement, in terms of consistency of very low and significant *p*-values for all questions. All *p*-values in this dimension are significantly low, with several of them in the range of 10^(−13) to 10^(−16), indicating that improvements in this dimension were highly significant and consistent across all questions evaluated. This suggests that training had a particularly strong impact on knowledge and adoption of these technologies. But it was also evident that the "Digital Culture" dimension showed the least improvement, this is because one question within this dimension (A-CD-4 vs. D-CD-4) did not show a statistically significant change, with a *p*-value of 0.249. Although other questions within this dimension showed significant improvements, the presence of a non-significant result suggests that the overall improvement in "Digital Culture" was less consistent compared to other dimensions evaluated.

4.4 Analysis of significant difference by dimension

In this study, the analysis of the significant difference was carried out for each of the dimensions present in the pre-test and post-test, grouping the total of its questions, which would indicate that it is unlikely that the variation observed is due to chance, but to a real effect.

Table 8 shows the analysis performed by dimension evaluating the impact of digital transformation in a higher education institution, considering the six key dimensions: important principles and definitions (D1), technological support for digital transformation in higher education (D2), digital tools (D3), disruptive technologies (D4), security in information and communication technologies (D5), and Digital Culture (D6). Using the Wilcoxon nonparametric test for related samples, significant differences were found in all dimensions between pretest and posttest scores. In dimension D1, related to basic principles of digital transformation, the *p*-value was 2.47×10^{-11}, indicating considerable progress. In D2, which covers technological support in education, the *p*-value was 1.55×10^{-12}, also reflecting significant improvement. For D3, which deals with digital tools, a *p*-value of 2.36×10^{-8} was obtained, evidencing progress in the use of these tools. Dimension D4, related to disruptive technologies, showed one of the most marked changes with a *p*-value of 9.08×10^{-17}, suggesting a notable adoption of these technologies. In D5, ICT security, a *p*-value of 6.30 × 10-15 was observed, highlighting the

TABLE 8 Significant difference by dimension.

Dimension	Wilcoxon statistic	*p*-value
Principles and definitions (D1)	5,240	$2.4655980216528618e^{-11}$
Technological support for DT in higher education (D2)	4,330	$1.5476674566063835e^{-12}$
Digital tools (D3)	9,845	$2.3607389033430527e^{-08}$
Disruptive technologies (D4)	1,360	$9.079004172432318e^{-17}$
ICT Security (D5)	2,320	$6.296403528118721e^{-15}$
Digital culture (D6)	3,560	$1.2996381711679942e^{-12}$

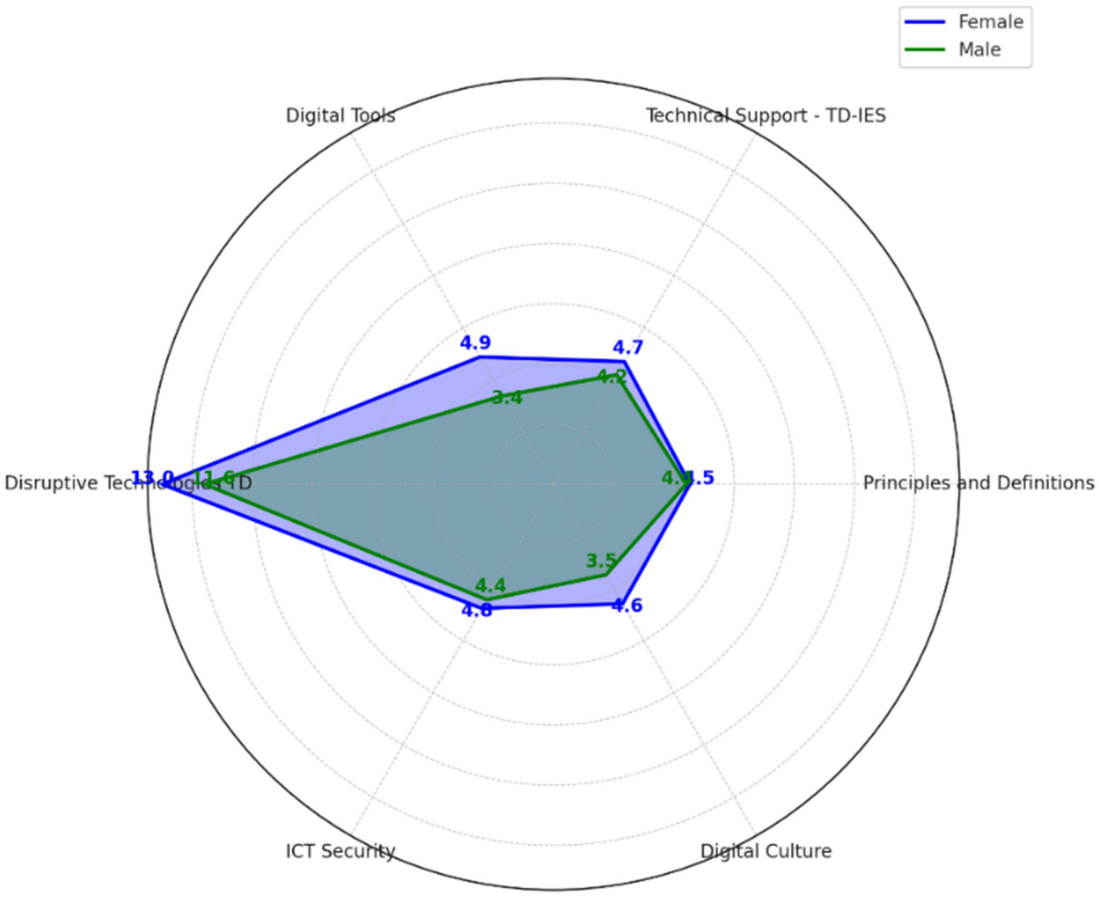

FIGURE 1
Differences between male and female scores by dimension.

growing importance of digital security in the transformation. Finally, in D6, related to training in digital technologies, improvements were also found with a significant *p*-value, reflecting the effectiveness of the training conducted in the adoption of new technologies. These results underscore the importance of comprehensive training and robust support for an effective digital transition.

4.5 Dimensions analysis by gender, role and age range

A comprehensive analysis was conducted to compare the impact of the training based on gender (Female/Male), performing a differentiated analysis of the results of the pre and post-tests for each of the six dimensions, taking into account gender to identify if there were significant differences in the improvement of knowledge in men versus women, based on the results obtained from the Wilcoxon test for the six dimensions previously evaluated.

First, the data were segmented by gender, then the Wilcoxon test was applied separately to each dimension, and the percentage change between the pre-test and post-test was calculated, which will allow us to quantify the impact of the training in a more intuitive way. Finally, a graph of these differences is shown.

Figure 1 compares the scores of men and women in all dimensions related to digital transformation. We observe that, in general, women have higher scores in almost all the dimensions evaluated, especially in Digital

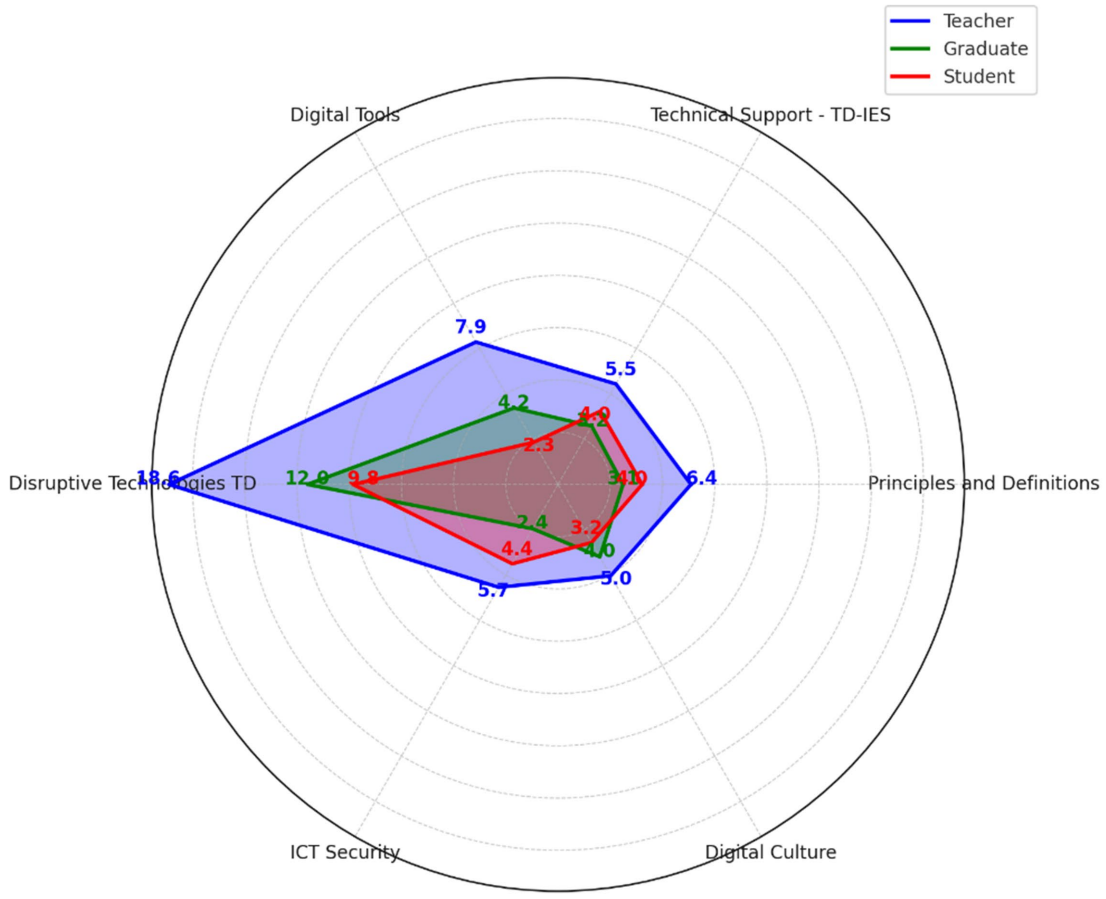

FIGURE 2
Differences in scores by roles in the six dimensions.

Tools and DT Disruptive Technologies. This suggests a more favorable perception or self-report by women regarding their level of interaction or competence in these dimensions. In contrast, men show slightly lower scores in these dimensions, although the differences are less pronounced in Technology Support and ICT Security. This visualization provides a clear comparison of gender differences, showing that women perceive greater mastery or support in several key dimensions of digital transformation.

Figure 2 allows us to visualize the differences in the perception of digital transformation according to the role (teacher, graduate and student). Teachers show the highest scores in almost all dimensions, standing out especially in Digital tools and Disruptive technologies, suggesting a greater use or familiarity with these technologies. Graduates show intermediate scores, with a good performance in Disruptive Technologies, although notably lower in ICT Security. Students, on the other hand, have the lowest scores, especially in Digital Tools and Culture, which could indicate less exposure or training in this dimension. These differences suggest that the roles are associated with different levels of digital transformation knowledge, with teachers being the most advanced and students the least familiar, which could be related to experience and time of use of the technologies.

Figure 3 shows the results of the assessment based on age ranges highlighting the 35–44, 45–54 and 55–64 ranges with higher scores in the Disruptive Technologies dimension. On the other hand, participants in the 35–44 age range obtain the highest scores, particularly in the Principles and Definitions and Disruptive Technologies dimensions, suggesting a high level of knowledge and adoption of technological advances. Finally, the 55–64 range, shows strengths in Digital Culture and Disruptive Technologies. These results suggest that older generations have a more advanced understanding of the key dimensions of digital transformation, probably due to their professional experience and prolonged exposure to technological evolution.

4.6 Satisfaction analysis

Three satisfaction questions were added to the post-test, which were answered by each of the participants. This information was processed in the following table.

Table 9 shows the descriptive analysis of the satisfaction questions that were included in the post-test giving the following results: regarding question 1 Are you satisfied with the content of the digital transformation event? a mean of 4.49 was obtained indicating that the participants are quite satisfied, regarding question 2 Was the information presented at the event relevant and useful? a mean of 4.41 was obtained, a little lower than the result of question 1 but indicating that participants are relatively satisfied and finally question 3 Would you recommend this event to others interested in digital transformation? a mean of 4.55 was obtained, which is the highest of the three, understanding that most of the

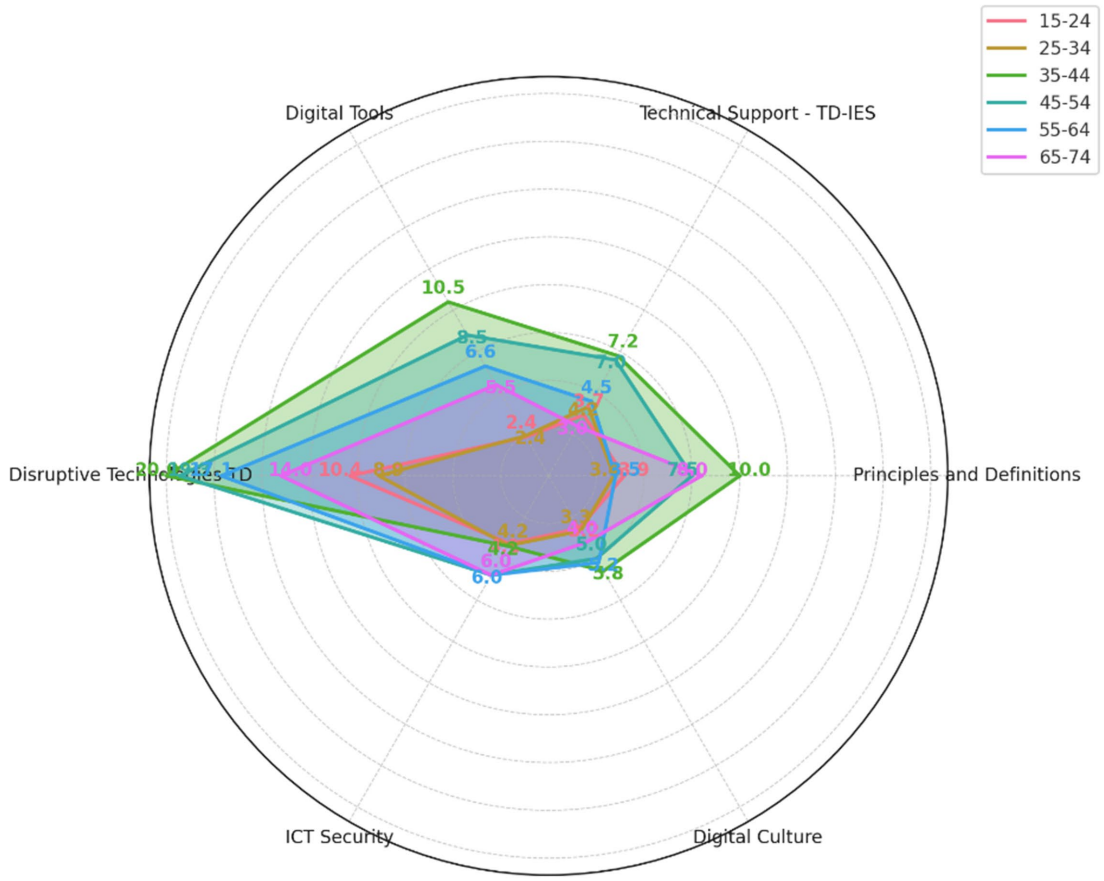

FIGURE 3
Differences in scores according to age range by dimension.

TABLE 9 Descriptive statistics based on the satisfaction questions.

Satisfaction questions	*N*	Minimum	Maximum	Media	Standard deviation
D-NS-1	107	2	5	4,49	0,664
D-NS-2	107	2	5	4,41	0,739
D-NS-3	107	3	5	4,55	0,648

TABLE 10 Satisfaction based on gender.

Genre	D-NS-1 Media	D-NS-1 Standard deviation	D-NS-2 Media	D-NS-2 Standard deviation	D-NS-3 Media	D-NS-3 Standard deviation
Male	4,49	0,674	4,38	0,728	4,52	0,657
Female	4,47	0,624	4,59	0,795	4,71	0,588

participants would recommend participating in this event to other people.

Table 10 presents the results of the segmented analysis by gender, revealing that both men and women have positive perceptions with respect to the three questions. On the first question, the mean for men is 4.49, slightly higher than that of women, which is 4.47. The median in both groups is 5, indicating that at least half of the participants of both genders gave the highest scores. Regarding question 2, a marked difference is seen more in women with 4.59 than men with 4.38, but the standard deviations are different, with women showing slightly more consensus in their responses (0.795 vs. 0.728). Considering the third question, men have a mean of 4.52, while women present a mean of 4.71. In this case, the standard deviations vary, suggesting that the opinions are not similar between them. In summary, the differences observed in the means are minimal, suggesting a consensus in the satisfaction of the participants regardless of gender.

Table 11 shows the analysis segmented by role, revealing that teachers, students and graduates have positive ratings in the three satisfaction

questions, although with minor variations among them. In the first question, teachers obtain the highest mean (4.68), unlike graduates (4.44) and students (4.43) who are very similar. The median is 5 across all roles, indicating that at least half of the participants in each group gave the highest score. The standard deviations are relatively low, suggesting a consensus in the answers given by each. For the second question, graduates show the highest mean (4.67), with teachers close behind (4.64) and students with lower values (4.32). Again, the median result is 5 in all groups, which reinforces the always positive trend in the answers given. And finally, with respect to the third question, graduates (4.89) have the highest score, teachers (4.77) have lower scores, and students with a much lower median (4.45). The median continues to be 5 in all roles, and the standard deviations continue to be low, these results indicate that there is variability in the responses of graduates and teachers and little variability in the students. Thus, finally, the results show a high degree of positive satisfaction among the different roles in the study, with minor differences suggesting a general consensus in the ratings.

According to Table 12, the analysis based on age range reveals that all ranges have positive ratings with respect to the three satisfaction questions, although with slight variations in the means. Participants aged 15–24 years have a mean ranging from 4.36 to 4.47. And it maintains a standard deviation above 0.65 which indicates a greater variability in the answers with divergent opinions. On the other hand, for participants aged 25–34 years its mean fluctuates between 4.33 to 4.5 a little higher than the previous age range, this group shows a similar positive perception with a standard deviation above 0.72 suggesting a relatively strong consensus in the valuations. For the 35–44 years old participants have a mean between 4.7 and 5.0, indicating a very favorable perception with a standard deviation of 0.5 and in the last question a deviation of 0.0 which indicates that there is no variability in the answers. The range corresponding to 45–54 years presents a mean of 4.70 to 4.80, suggesting that the ratings are consistent in this group. In the 55–64 years range the mean is 5.0, presenting the lowest score of all the ranges, and finally the 65–74 years range presents the highest mean (5.00) and the lowest standard deviation (0.0), which indicates that there is no variation in their responses, taking into account that the scores are always positive.

Finally, the overall analysis based on the ranges suggests that all age ranges have favorable perceptions towards the satisfaction questions evaluated, with slight variations in the means that reflect a general consensus. These results may be useful for targeting intervention or communication strategies based on the differences in satisfaction between the age ranges assessed.

Discussion

The research in question proposes the evaluation of six defining dimensions with the aim of confirming the level of knowledge and adoption of digital transformation in a higher education institution, from elementary notions to the actual application of disruptive technologies; the results achieved report a significant increase in the dimensions following the training conducted. Thus, the validity of this is confirmed. Regarding the fundamental principles and concepts dimension, improvements were observed in most of the items (p-values < 0.001). This is the same result found in research such as that of Trevisan et al. (2024), who emphasize that higher education institutions should adopt consistent practices in relation to digital transformation, which in turn contribute to an improvement in educational quality and accessibility. Others, such as A-PD-2 (Do you know what innovation is) and A-PD-4 (Do you know that access to data in real time allows you to process and obtain information immediately), show improvements that are not confirmed by statistically significant differences, which indicates that they still need to be reinforced by carrying out technical workshops focused on innovation and information management, thus following the line of the barriers alluded to by the work of Sydorenko et al. (2024) in relation to the gaps that persist in the digital culture identified between institutions, we have question A-CD-4 (Are you willing to be part of the DT?) also does not present significant differences, which is why the lack of willingness of the staff to get involved in the DT process is understood, this leads us to propose future workshops that include more members of the university community.

TABLE 11 Satisfaction based on role.

Role	D-NS-1 Media	D-NS-1 Standard deviation	D-NS-2 Media	D-NS-2 Standard deviation	D-NS-3 Media	D-NS-3 Standard deviation
Teacher	4,68	0,477	4,64	0,581	4,77	0,429
Student	4,43	0,718	4,32	0,787	4,45	0,700
Graduate	4,44	0,527	4,67	0,500	4,89	0,333

TABLE 12 Satisfaction based on age range.

Age range (years)	D-NS-1 Media	D-NS-1 Standard deviation	D-NS-2 Media	D-NS-2 Standard deviation	D-NS-3 Media	D-NS-3 Standard deviation
15 a 24	4,42	0,700	4,36	0,760	4,47	0,653
25 a 34	4,46	0,721	4,33	0,816	4,50	0,780
35 a 44	4,75	0,500	4,75	0,500	5,00	0,000
45 a 54	4,70	0,422	4,80	0,483	4,70	0,422
55 a 64	4,38	0,518	4,37	0,744	4,63	0,581
65 a 74	5,00	0,000	5,00	0,000	5,00	0,000

In relation to the Technological Support dimension, the results examined a significant positive impact, with p-values < 0.001, giving value to having technological support as a key element when implementing digital transformation, as others have pointed out (e.g., Jabborova et al., 2024). In this regard, we confirm that technological support can be considered a determining element in the modernization of universities, as this author also confirms in his work, i.e., that investing in this area is key. Regarding the improvements in the Digital tools dimension, we also found significant results, with consistently low p-values; this means that participants increase their comfort levels with digital tools, such as Zoom, etc.

6 Conclusion

The present study shows that the level of knowledge in digital transformation in the university community increased after conducting the training, evidencing that teachers had the highest level in relation to the roles of graduates and students, especially in the dimensions of disruptive technologies and digital tools, in addition, shows that graduates are at an intermediate level of knowledge and finally students are being considered with a lower level, especially in the dimension of digital culture and digital tools, this confirms that we must continue to develop progressive training for the university community in order to further increase their level of knowledge in digital transformation.

Regarding the university community's level of knowledge regarding key principles and definitions of technology and DT, the results showed significant improvements. However, concepts such as innovation and real-time data access did not show any improvement, indicating that we need to address these topics in a more practical way, developing applied examples that connect with the participants' real-life roles and experiences. Regarding knowledge of the technological support that supports DT, participants showed varying levels, with a tendency to lack familiarity with how institutional systems work. The training provided a better understanding, which should be strengthened, especially among those profiles less exposed to university technology management. Regarding knowledge of digital tools, both faculty and students demonstrated high familiarity with resources such as virtual platforms and collaborative tools, providing the opportunity to expand this knowledge to more advanced and integrative tools that enhance the strategic use of technology. Regarding knowledge of disruptive technologies, a significant improvement was evident after the training, although this knowledge continues to be focused on certain disciplines, especially in technology programs, which allows for the implementation of differentiated strategies according to the participants' academic profile. Furthermore, this study shows that knowledge of cybersecurity is general, but with some gaps in the application of best practices. The implementation of the training allowed for improvement in this dimension, but it is recommended to strengthen it through modules focused on the protection of personal data, passwords, and secure browsing for the university community. The perception of digital culture was seen as a dimension that shows resistance to change due to low participation in the institution's DT process. It is necessary to implement motivational and institutional participation strategies to reduce this resistance.

It is worth highlighting the need to promote the adoption of disruptive technologies and facilitate an effective transition to digital educational environments through targeted training for the various roles identified. Furthermore, it is important to establish strategies to consolidate a collaborative ecosystem that involves the entire university community, with the aim of enhancing the flexibility of HEIs by ensuring an effective transition to digital education models, including technological infrastructure and technical support that enables work in environments oriented toward innovation and experimentation that explore new digital methodologies.

6.1 Principal contribution

This work makes a fundamental contribution by demonstrating that educational interventions are capable of having a significant impact on the adoption of knowledge and disruptive technologies in a HEI. Additionally, it highlights the need for an integrated strategy that goes from technological support to ICT security, digital culture, for example, in order for a digital transformation to take place.

Our research provides clear and specific evidence of how these principles are applied and operationalized in one HEI in Peru. This study not only reinforces what we already know, but also highlights the importance of having a comprehensive, DT-aligned strategy for knowledge transfer. It also provides practical insights that other similar HEIs in the region can use.

6.2 Limitations

An important limitation of the study is the use of a single database, which may restrict the generalizability of the results. The analysis was based only on data obtained from one institution, so it would be beneficial to extend the study to other universities to validate the findings, adopting diverse sampling strategies to obtain a result that ensures more equitable representation in terms of participants' gender and degree programs.

6.3 Perspectives and orientations

Future researchers should focus on exploring how different institutional contexts affect the adoption of disruptive technologies and the development of a digital culture. It would also be useful to analyze the effects of more specific educational interventions on different groups within the university community, such as students versus teachers, in order to customize training strategies. Finally, further research on the relationship between technological support and academic performance in digital education is suggested to ensure that HEIs continue to move towards a comprehensive and sustainable digital transformation.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JA: Formal analysis, Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation,

Conceptualization. RA: Data curation, Formal analysis, Methodology, Conceptualization, Writing – review & editing, Investigation, Writing – original draft. LG: Formal analysis, Writing – original draft, Methodology, Data curation, Conceptualization, Writing – review & editing, Investigation. JB-J: Investigation, Conceptualization, Writing – review & editing, Data curation, Methodology. NG: Investigation, Conceptualization, Writing – review & editing, Data curation, Methodology. CV-S: Investigation, Data curation, Writing – review & editing, Methodology, Conceptualization. OS: Writing – review & editing, Data curation, Methodology, Investigation, Conceptualization. GM-N: Conceptualization, Writing – review & editing, Supervision, Methodology. AT-A: Writing – review & editing, Supervision, Methodology, Conceptualization.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

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