Digital Transformation: Perspectives and Post-Pandemic Adaptation in the Education Sector – A Case Study

Transformación digital: percepciones y adaptación post pandemia en el sector educativo – un estudio de caso

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ABSTRACT

The digital transformation of the public sector seeks to create an effective and efficient government through technology. In the education sector, the pandemic accelerated the adaptation process and the use of new technologies, evidencing, at a global level, complex situations related to university activities and their adaptation to virtuality. This work presents a study conducted at Universidad Nacional de Colombia following the 2020 crisis, which sought to determine the perception of digital transformation within the institution. A study framed within a descriptive methodology was conducted to validate the advances and challenges that persist in relation to the digitization of the university's activities. All this was based on a non-probabilistic sample of 519 people from the academic community. The main results indicate the existence of context-related aspects that facilitate or represent barriers regarding the use of digital tools, such as age, territory, and university campus. The main issue associated with information and communication technologies is Internet access, followed by physical access to related infrastructure and the lack of skills. In addition, we observed a preference for mixed modalities by students, who indicated a desire for change in the education model. Lastly, the applied instrument is highly reliable, which is why it can be used and complemented for future studies under more favorable conditions.

Keywords: education, distance education, COVID-19, pandemic, digital transformation, digital divide

RESUMEN

La transformación digital del sector público busca crear un gobierno eficaz y eficiente a través de la tecnología. En el sector educativo, la pandemia aceleró el proceso de adaptación y el uso de nuevas tecnologías, evidenciando, a nivel global, situaciones complejas relacionadas con el quehacer universitario y su adaptación a la virtualidad. Este trabajo presenta un estudio elaborado en la Universidad Nacional de Colombia, posterior a la crisis del 2020, que buscó establecer la percepción de la transformación digital en la entidad. Se desarrolló un estudio con una metodología descriptiva, en aras de validar los avances y retos que persisten en relación con la digitalización de la universidad en sus actividades. Esto, a partir de una muestra no probabilística de 519 personas de la comunidad académica. Los principales resultados indican que existen aspectos de contexto que facilitan o representan barreras respecto al uso de herramientas digitales, tales como la edad, el territorio y la sede universitaria. El principal problema respecto a las tecnologías de la información y las comunicaciones es el acceso a Internet, seguido del acceso físico a la infraestructura relacionada y la falta de habilidades. Además, se percibió una preferencia por la modalidad mixta por parte de los jóvenes, indicando un deseo de cambio en el modelo educativo. Por último, el instrumento utilizado es altamente fiable, por lo que puede ser utilizado y complementado para futuros estudios en condiciones más favorables.

Palabras clave: educación, educación a distancia, COVID-19, pandemia, transformación digital, brecha digital

Introduction

The COVID-19 pandemic disrupted the daily activities of various actors in society [1]. One of the most affected sectors in terms of practices and modes of operation was education, which was strongly restricted for almost two years, during which it could not tend to its pedagogical work in the *traditional* manner [2]. In particular, the university education sector faced severe restrictions for an almost continuous period of two years [3], given the volume of people who could have been affected by the crowds.

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This scenario revealed the need to adapt to the new conditions of isolation in order to continue guaranteeing access to higher education in Colombia, despite the socioeconomic effects derived from the pandemic [4]. Some studies in the education sector, particularly in higher education, have explored and investigated students' perceptions regarding the 'adapted' teaching-learning processes implemented during the contingency [5]. Other authors have conducted qualitative studies related to the innovative factor that triggered the digital transformation in the work of educators across 10 different universities in Latin America [6].

Universidad Nacional de Colombia (UNAL) was no stranger to this situation, which is why it had to undertake, with varying degrees of success, different actions aimed at adapting its missional functions, *i.e.*, research, teaching, and extension [7]. The university started treading a path with considerable uncertainty regarding possible effects and results [8], which also required quick decisions to minimize aspects such as dropout, the shutdown of its academic-administrative operation, and the interruption of processes that had been proposed [9] and implemented in the institution before the pandemic [10], [11].

Under these circumstances, technological tools proved to be a necessary and even essential ally, even for those with strong positions against them due to risks related to academic quality and teamwork, among others [12]. In addition, the difficulties and challenges posed by the adaptation, *i.e.*, focusing the entirety of university activities on digital and distance channels without adequate pedagogical preparation and technological skills due to the imminent closure [13], implied little time to plan and respond [14]. As for the digital transformation processes, it was essential to create technological (connectivity, infrastructure), cultural (adaptation to change), and human resource management (leadership and coordination) conditions in place, so that these initiatives could modify both the processes and the results obtained (efficiency, effectiveness, effectiveness).

To accelerate the digital transformation, different mechanisms and tools associated with the use of technology in teaching-learning processes were sought [15]. One of the strategies led by UNAL through the Laboratory-University Division (UNALab), with the support of the Innovation, Creativity, and New Technologies Laboratory LAB101 UNAL, had to do with understanding the use of technologies and the way in which the academic community was coping with the pandemic, as well as the actions undertaken through different strategies or activities aimed at mitigating the difficulties caused by isolation. To this effect, an instrument was built. One of its first approaches involved understanding the context and the way in which the academic community was dealing with the situation, seeking to determine a set of actions to support decision-making concerning the different needs identified in the short and medium term. Although UNAL defined a digital transformation strategy [10], [11], which was tested in a context of uncertainty, it is essential to assess and verify, through various studies, whether this strategy added value

to the institution's operations. This is particularly important given that some studies indicate that only one in four higher education institutions (HEIs) with a digital strategy perceive any 'valuable return' in terms of organizational impact or cultural change among their members [16].

For this study, two specific objectives were proposed:

- To determine the perception of the academic community (teachers, students, administrators, and contractors) regarding the use and acceptance of technologies in their educational work after the pandemic

- To validate whether there are relevant aspects associated with the context (rural, urban, municipal capitals, campus, among others) that facilitate or generate barriers around the use of digital tools and information and communication technologies (ICTs) in academic-administrative activities

Materials and methods

Instrument for measuring the perception of the digital transformation

A survey was designed to obtain information regarding the main perceptions of the members of the university community on explicit issues related to development and digital transformation in higher education during and after the pandemic. It provided an approximate look at the disruption caused by new technologies in the university scenario during the health emergency due to COVID-19. The questions were designed according to some of the main axes or themes for measuring digital processes mentioned in *Higher education data collection in Hungary and considerations for the development of indicators*, a section of the document titled *Supporting the digital transformation of higher education in Hungary*, issued by the Organization for Economic Cooperation and Development [17]. This document discusses digital infrastructure, digital skills, the environment, and digital culture. The analyzed axes and themes were modified according to the reality of Colombia, and a component with sociodemographic questions was added, allowing to disaggregate the respondents' information, thereby enriching the research on issues of population distribution and access to basic conditions for the use of new technologies.

The instrument contained two types of questions with three approaches. The first type included multiple-choice questions with a single answer, aiming to characterize the respondents according to sociodemographic aspects and the main factors of digital transformation. The latter assessed the digital infrastructure axis (*e.g.*, Internet access). The second type included perceptual questions associated with a Likert scale-type response (*i.e.*, a psychometric scale), where the respondent had to indicate the degree of agreement or disagreement with a statement or item. The

Likert scale was selected since this type of aggregate rating measures is relevant and common in measuring phenomena associated with feelings, attitudes, or perceptions [18], [19]. These questions primarily focused on measuring the axes of digital competences, the environment, and digital culture.

The responses to the virtual form were collected by means of snowball sampling, *i.e.*, a non-probability sampling method in which a set of selected subjects incorporates other subjects into the study [20] (in our case, this was done via e-mail). This sampling methodology was selected since, due to the characteristics and conditions of the confinement measures implemented by public health entities at the time [21], there was no guarantee of defining a relevant and appropriate random sampling framework for all the university's campuses, nor could the researchers go and survey subjects in person with all the conditions that the situation required.

Analysis and data

To analyze the data, only exploration and statistical description tools were applied, namely contingency tables; cake and doughnut diagrams; bar graphs; stacked Likert bars; a correlogram, where a polychoric correlation was used [23]; and boxplots, to which an argument of variation was applied. Since it adds a slight random alteration to the points in order to visualize those that overlap, this argument only had a visual effect and was not used for statistical tests. Regarding the consistency of the instrument, a reliability analysis was conducted, mainly using Cronbach's Alpha [24] and Guttman's Lambda 6 [25]. On the other hand, association and group comparison tests were used: Chi-Square to test for association [26], Cramér's V to determine the strength of association, and Wilcoxon Mann-Whitney with Holm adjustment to test the difference between groups [27], [28]. Additionally, a dimensionality reduction analysis was performed to measure and find associations between variables (MCA), and data mining methods were applied to identify underlying patterns in the data, *i.e.*, HCPC and K-Means [29]. However, the latter did not yield significant results, which is why they are not presented in this document.

The tools used to analyze the information were Excel and R. Organization and debugging were carried out in the former. It is important to mention that 538 answers were initially obtained, and that filtering the data resulted in 519 responses. Meanwhile, R was used for a basic visualization of the primary variables. It should be noted that, in order to make the presented figures friendlier, the viridis color palette was used, which was designed to allow for greater precision in interpreting scientific data, mainly for people with color vision deficiency. In addition, reliability analyses of the instrument were carried out, *i.e.*, tests of association and differences between groups, Likert-type response visualization (using the Likert library) [30], and association and clustering analysis.

To interpret the tests, a significance value of 0.05 was used. This means that, for a given hypothesis, it is determined whether the p-value is less than 0.05. If so, the hypothesis is rejected; otherwise, it is not rejected. The hypotheses may vary, but, for this study, the null hypothesis implied an association between variables or, failing that, a difference between groups. On the other hand, for the correlations and Cramér's V, the criteria shown in Tables I and II were used.

Table I. Criteria for interpreting Cramér's V

Effect size	Interpretation
ES ≤ 0.2	The result is weak. Although the result is statistically significant, the fields are only weakly associated.
0.2 < IS ≤ 0.6	The result is moderate. The fields are moderately associated.
ES > 0.6	The result is strong. The fields are strongly associated.

Source: Cramér's V [31]

Table II. Criteria for interpreting the correlations

Coefficient range	Interpretation
0-0.19	Very low correlation
0.2-0.39	Low correlation
0.4-0.59	Mean correlation
0.6-0.79	Strong correlation
0.8-1	Very strong correlation

Source: [32]

Results

The results obtained through the developed instrument are shown below. They are grouped in relation to (i) the sociodemographic aspects of the respondents, (ii) the general context of the digital transformation and the variables associated with access and connectivity, and (iii) the perception of the digital transformation in the context of work and education.

Sociodemographic aspects of the respondents

519 respondents participated in this study, out of which 56.5% identified themselves as male, 42.2% as female, 0.6% as non-binary, and 0.6% preferred not to declare. This is depicted in Fig. 1. It should be noted that there was a high participation of the age groups 18-23 and 24-29 (Fig. 2), with 34.5 and 16.6%, respectively. Meanwhile, for the age groups between the ages of 30 and 65, the average percent participation was 6.9% – for those under 18 and over 65, the value was less than 8%. However, 90.2% of the participants live in urban areas, 9.2% in rural areas, and the other 0.2% in other locations, alternating between rural and urban, municipal, and semi-rural capitals (Fig. 3). The responses are concentrated in the Bogotá and Medellín campuses, as can be seen in Fig. 4.
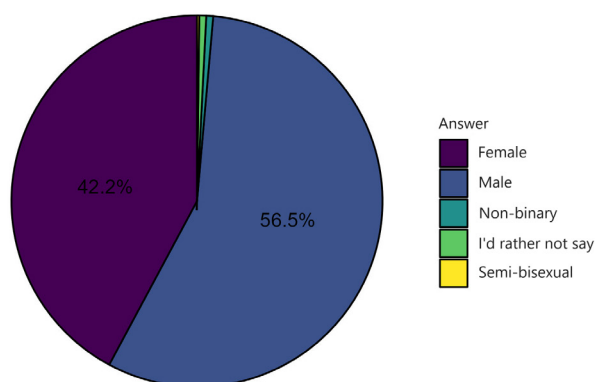
Figure 1. Sociodemographic data by gender
Source: Authors
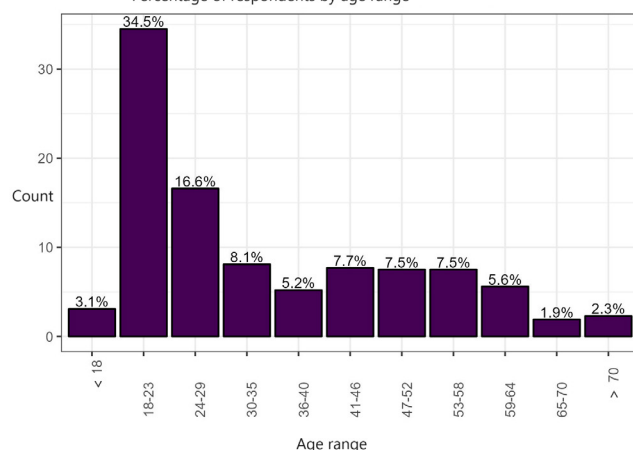
Figure 2. Sociodemographic data by age
Source: Authors

Figure 3. Sociodemographic data by place of residence
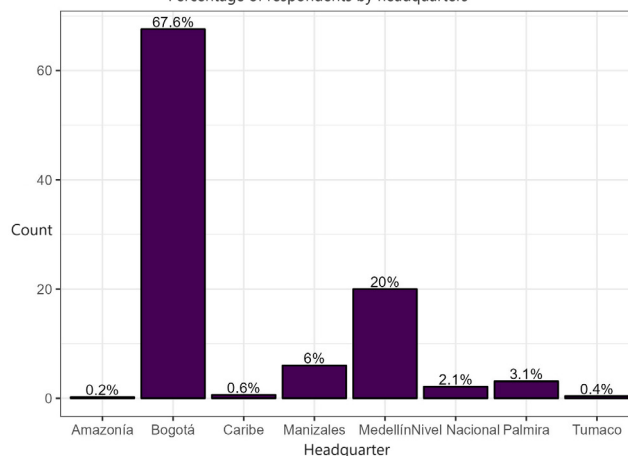**Source:** Authors

Figure 4. Sociodemographic data by UNAL campus
Source: Authors

General aspects of digital transformation in the university community

Within digital transformation models, digital infrastructure is highlighted as a highly relevant dimension. The university community was asked about basic aspects associated with the availability of the necessary infrastructure for their digital processes, such as access to quality electricity, a strong Internet connection, and the corresponding technological devices. For instance, Fig. 5 shows that the community was able to access the Internet mainly from home.

One of the relevant indicators to evaluate Internet quality is the contracted browsing speed. According to the survey, 34.5% of the respondents contracted more than 50 megabits per second (Mbps), 21.8% had 26-50 Mbps, 11% had 16-25 Mbps, 17.3% had 6-10 Mbps, 6.9% had 11-15 Mbps, and 8.5% reported less than 5 Mbps (Fig. 6).
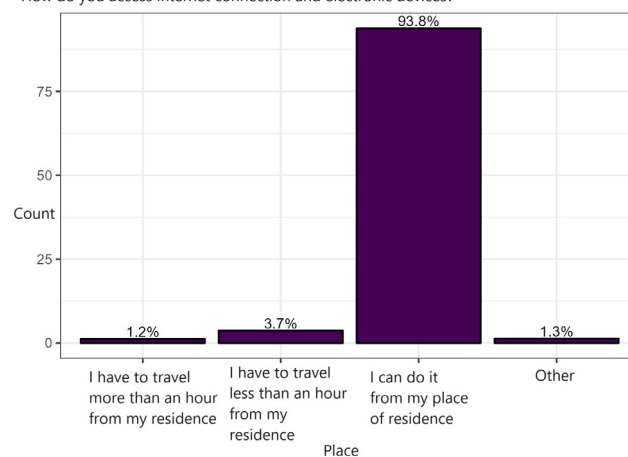

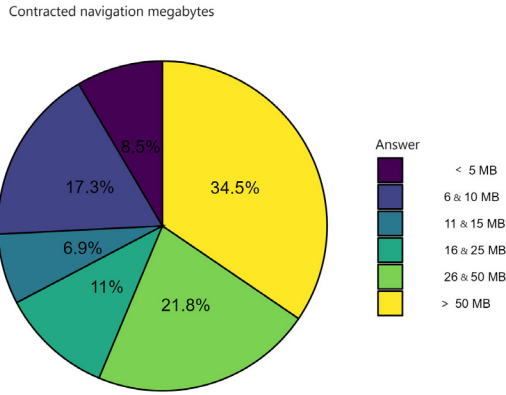**Figure 5.** Internet access data
Source: Authors

Figure 6. Type of access and capacity of the respondents' Internet service
Source: Authors

Fig. 6 indicates that the ICTs currently used by the respondents in their roles allow them to completely (73.6%) or partially (25.4%) solve problems, challenges, or difficulties. Within this group, 21.8% indicated advanced skills, 65.9% intermediate skills, and 12.3% basic skills (Fig. 8). Meanwhile, 1.0% of the respondents gave a negative answer to this question.
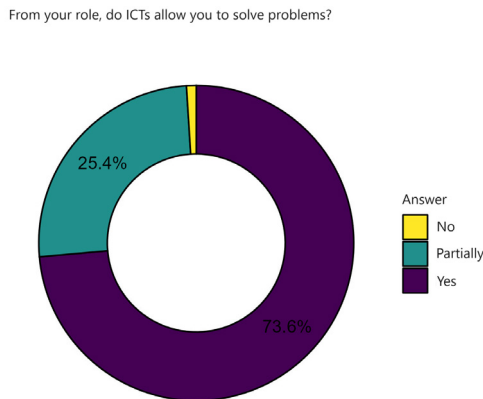

Figure 7. Appropriation of digital skills
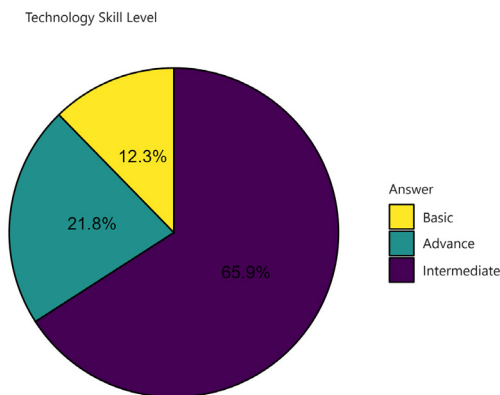**Source:** Authors

Figure 8. Digital skills level
Source: Authors

Additionally, as can be seen in the figures below, three important aspects should be highlighted. Regarding digital culture in the university community, 18.5% of the respondents indicated that the university is not a beacon of digital transformation. However, 21.6% declared the opposite. The former was partially supported by 59.9% of the respondents, who considered the university to be partially leading the digital transformation (Fig. 9).

On the other hand, Fig. 10 shows that 59.9% of the participants consider the use of digital technologies by UNAL to partially respond to the needs of the university community or society in general. 27.6% indicated that the use of technologies fully responds to the needs of individuals within and outside the institution. Only 12.5% provided a negative response to the statement.

Additionally, we asked if the processes conducted within the university have become more efficient with the use of digital technologies. 45.9% of the respondents considered this to be partially true, 43.2% provided an affirmative answer, and 11% responded negatively. The responses are summarized in Fig. 11.
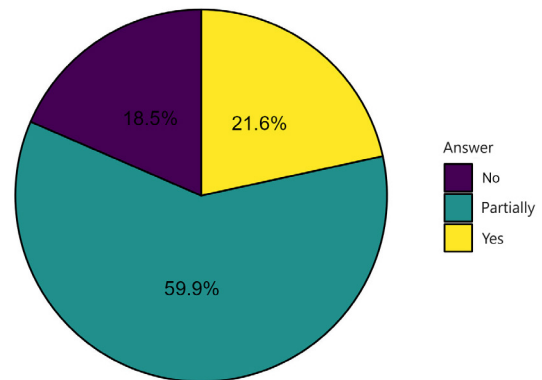

Figure 9. Perception of digital processes at the university
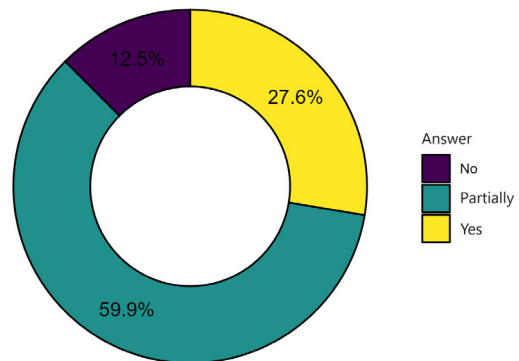**Source:** Authors

Figure 10. Perception of the response of digital technologies to the needs of the university community
Source: Authors

Have the processes at UNAL become more efficient with the use of digital technologies?
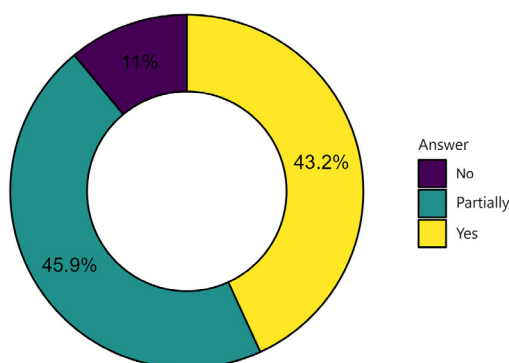

Figure 11. Perception of the use of ICTs in university processes
Source: Authors

Perception of the digital transformation in the university community

To validate whether the instrument was consistent and helped to address the questions we aimed to answer, we initially assessed it using Cronbach's Alpha. Table III shows an evaluation of the reliability of the Likert-type responses used in the second and third sections of the instrument to validate the subsequent analyses via Cronbach's Alpha and Guttman's Lambda 6.

Table III. Reliability test results

Alpha based on correlations	Standardized alpha based on correlation	Guttman Lambda 6 reliability	Average correlation between elements	Standard deviation of the total score	Median correlation between elements
0.82	0.83	0.84	0.36	0.55	0.36

Source: Authors

Table III shows high reliability or internal consistency, with a Cronbach's Alpha of 0.82 and a Guttman's Lambda 6 of 0.84. For a high level of consistency in the instruments, the values of these coefficients should be greater than 0.8 [22] However, the average correlation between the items is 0.32, which indicates a low association between them.

To gain an initial understanding of the relationships between the variables in the instrument, an analysis of pairwise correlations was conducted. Given that the variables are ordinal and not continuous, we applied a polychoric correlation method, which provided insights beyond previous analyses focused on independently describing each question and response. By correlating variables, this method highlights the connections between the questions and the responses provided by the sample, allowing for a deeper exploration of the data's structure and implications.

The polychoric correlation shows moderate relationships between some of the variables. Considering that a moderate value is between 0.4 and 0.6, we can relate the variables associated with digital competencies or skills to most of the other variables in the figure, as well as to those related to the streamlining of processes thanks to the use of ICTs, which exhibit a medium correlation with several of the variables in the graph. In addition, there is a correlation of interest between access to ICTs and Internet access during the pandemic, as well as between the satisfaction with ICTs, the motivation to use them, and their frequency of use (Fig. 12).
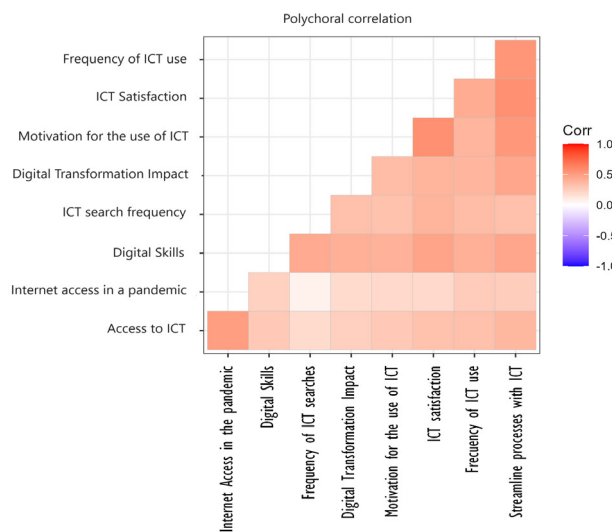

Figure 12. Polychoric correlation
Source: Authors

Fig. 13 summarizes the information obtained through five-point Likert-type responses. It should be noted that the graph indicates the proportion corresponding to each of the ratings per question and the percentage trend in descending order.
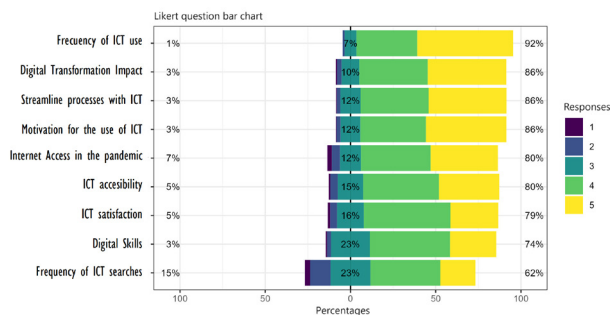

Figure 13. Bar chart for the Likert-type variables
Source: Authors

Fig. 13 shows that 92% of the people surveyed have a positive tendency to use ICTs in their activities, while 7% have a neutral position and 1% have a negative one. 86% of the participants expressed a positive preference regarding

the use of ICTs, 12% indicated a neutral position, and almost 3% did not perceive the use of these technologies to have streamlined their processes. Most of the interviewees were positively motivated to use ICTs, but not as satisfied: 79% indicated high satisfaction, 16% partial satisfaction, and 5% contrary satisfaction. However, 80% of the respondents stated that physical access to ICTs has been both easy and relatively easy, while 15% found it to be partially easy and 5% did not perceive it as easy.

Regarding digital environment and competence, Fig. 13 shows that 86% of the surveyed population have seen an impact on their daily activities. Moreover, 10% have a neutral position, and approximately 3% stated that the digital transformation has had no impact on them. Likewise, 74% rated their digital skills with using digital tools as high, while 23% indicated a central position, and 3% rated their digital skills as low.

Finally, the respondents were asked how often they searched for new ICTs to solve problems. 61% of them searched quite often, 15% did not do it so often, and 15% tended not to do it. They were also asked how difficult it was for them to access the Internet during the pandemic: 81% of the participants had difficulties with Internet access and 7% did not encounter major issues.

To analyze the differences between the categories of nominal variables with respect to the ordinal qualitative variables, the Wilcoxon test was employed, as well as the Holm method to adjust the p-value. The variables that showed significant differences between their categories are presented below, and said categories are specified.

Differences were found between genders in relation to technological skills and the motivation to use ICTs. Regarding the former, a p-value of 4.2e-07 was found, which is lower than the level of significance (p-value<0.05), between the male and female participants, i.e., there are differences between these groups. With respect to segmentation by university campus, in both Bogotá and Medellín, it can be clearly seen that males tend to rate their skills more positively than females (Fig. 14).

On the other hand, as can be seen in Fig. 15, there are differences in the territory categories with respect to Internet access during the pandemic. For the territory variable, the test yielded a p-value of 0.00089 between the urban and rural areas, indicating significant differences in the assessments provided by the participants in terms of their Internet access during the pandemic; a better perception was found in urban areas.
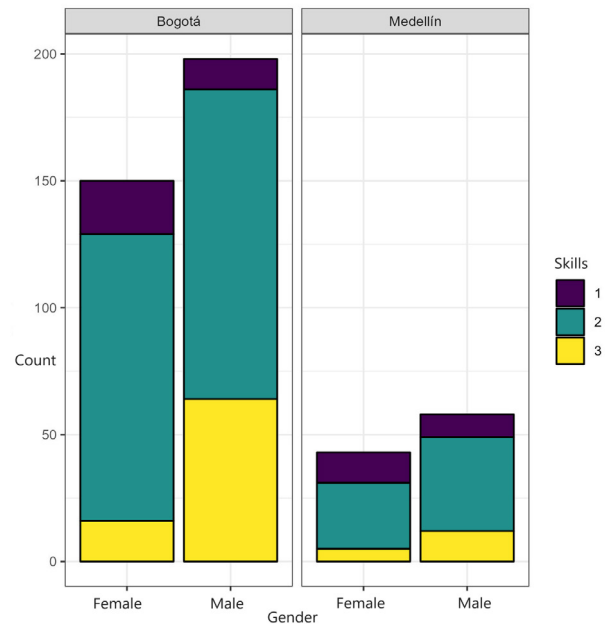

Figure 14. Bar chart for digital skills by gender and campus
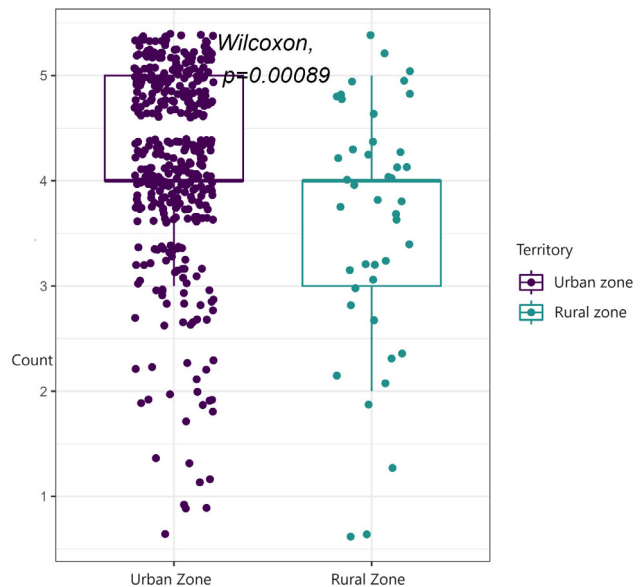**Source:** Authors

Figure 15. Internet access by territory during the pandemic
Source: Authors

Regarding segmentation by campus, Bogotá and Medellín exhibited the same behavior, but the latter showed no statistically significant difference (p-value=0.14) compared to the former (Fig. 16).
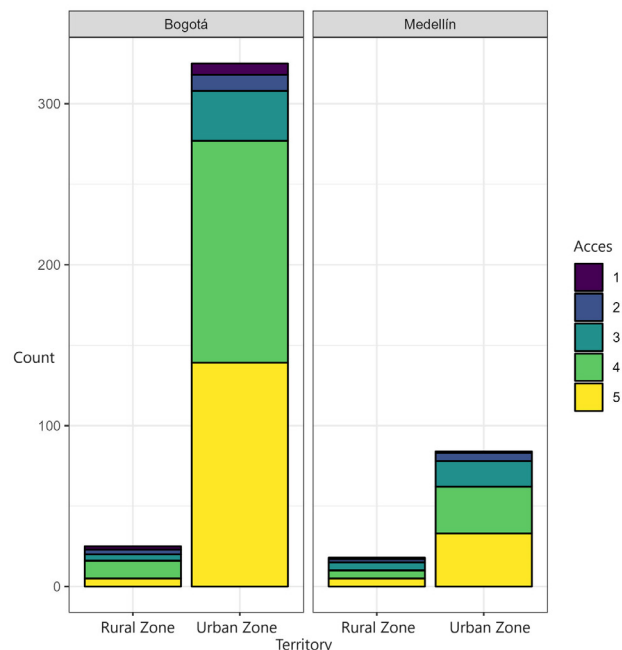
Figure 16. Internet access *vs.* territory
Source: Authors

Conclusions

Our instrument allowed collecting information on people from different contexts who are associated with UNAL, providing an initial idea of their knowledge and use of technology, especially among the population with access to the Internet.

According to the results, the surveyed UNAL community does not perceive the institution as a digital transformation leader in higher education. This aligns with and supports previous studies indicating that a digital transformation strategy is not commonly perceived by most HEIs to generate practical value for their development [16]. This implies, on the one hand, recognizing and better highlighting the efforts made by the institution with regard to the digital transformation, and, on the other hand, it necessitates a more accurate determination of the institution's digital maturity level, as well as the implementation of actions aimed at strengthening competencies in this area [33].

Regarding the barriers or challenges of implementing technologies in university settings, there are significant differences in male and female individuals' appropriation of and motivation to use ICTs. This finding holds great value in association with other studies suggesting that efforts for such appropriation should be focused on teacher training [6]. Our results reveal important gaps that should lead to the development of effective actions to mitigate this situation from the perspective of female students and their contexts [34].

It is also interesting that, in general, the findings indicate acceptance, knowledge, and use of ICTs in both professional and academic settings, with even a positive perception regarding the ease and speed that these tools provide in solving everyday problems. However, it is particularly noteworthy that the interest in seeking new ICT tools is relatively low. This suggests, as proposed by other authors, a need for strategies that promote interest in and knowledge of new tools or uses of ICTs in academic or professional contexts from the perspective of educational teaching, in order to foster curiosity about the use of new technologies [6], [35].

Initially, through Cronbach's Alpha, we identified a high level of reliability and consistency in the questions of the applied instrument. We observed higher participation by young people (mostly undergraduate students) aged between 18 and 23 years from the Bogotá and Medellín campuses. However, there were participants in all age ranges, from all campuses, and with different types of association with the university.

Furthermore, when analyzing the instrument's questions, associations were found between digital variables in relation to age, territory, and university campus, which implies context-related aspects that facilitate or generate barriers for the use of digital tools. Firstly, differences between territories were found with regard to Internet access during the pandemic. Secondly, differences between UNAL campuses were found in relation to the level of satisfaction expressed by participants when using ICTs, their perception of whether these tools help to solve day-to-day problems, and their opinion regarding the university as a benchmark in terms of digital transformation and the efficiency of ICTs. Thirdly, significant relationships were found between the gender variable in relation to technological skills and the motivation to use ICTs.

On the other hand, although most of the participants live in urban areas and have favorable perceptions regarding the use of ICTs, those in rural areas indicated that, despite the simplicity of physical access to digital devices, access to the Internet has not been easy. This reveals a need for better Internet distribution, accessibility, and coverage in the country, as most participants expressed it as a necessity.

In addition, the perception of the academic community regarding the use of technologies after the pandemic indicates that the main issues have to do with the lack of Internet access, followed by limitations in physical access to ICTs and lack of skills. Finally, we found that virtuality is currently used as a means of study or work, but that mixed modalities (e.g., blended learning) are significantly preferred by young people. Our tests also suggested a desire for change in the pre-pandemic educational model.

Recommendations and limitations

A more specific study on this issue could be carried out. Our sampling method allowed drawing conclusions descriptively, since it did not allow for generalization or inference. Still, it should be noted that the procedures could not have been more rigorous due to the confinement measures in effect during 2021.

In addition, three approaches were considered in this work: sociodemographic aspects, digital infrastructure, and perception of the digital transformation. These approaches were appropriate, understandable, and accessible to the respondents, in addition to covering part of the axes proposed by [17], i.e., digital infrastructure, digital skills, environment, and digital culture.

Given the need to perform snowball sampling during the pandemic and under the immediate post-quarantine conditions, the results of this work may be biased by the favorable conditions of those who were able to fill out the survey. Therefore, our results cannot be extended beyond the conditions presented by the respondents.

Additionally, we suggest carrying out a new test that allows contrasting our results, aiming to determine which variables or categories were altered or accentuated under the new conditions of work and study after UNAL resumed its 100% face-to-face classes. All this, in order to establish if teaching-learning processes continue to be facilitated or favored by the use of technology.

With the instrument applied, the information collected, and the adaptation of the Hungarian model that inspired the construction of our approach [17], longitudinal studies with several universities could be conducted, objectively comparing the progress made and the challenges present in the implementation of digital transformation strategies that add value to educational organizations [6].

In the future, more robust studies could be carried out to establish baselines of action, whose results should facilitate decision-making regarding the challenges faced by HEIs in digital transformation processes, in the use of technologies in the classroom, and in their acceptance by teachers, students, and administrators [8].

Additionally, we suggest undertaking new studies that deepen these preliminary findings, correct the biases inherent to our sampling and data collection processes, and confirm or complement the results obtained through implementations in other HEIs, enabling the generalization of the proposed indicators and the strengthening of comparative analyses [36].

Acknowledgements

CRediT author statement

J. A. García conceived the idea, proposed theoretical and empirical references to carry out this research within the framework of his doctoral thesis, and wrote a large portion of this text. **J. D. Niño and J. A. López** validated and analyzed the data, developed statistical models, and made important contributions to the document. **L. K. Quintero** reviewed and supported the deployment of the instrument within the academic community, provided suggestions, and helped to write this manuscript. **J. Bula** provided comments and suggestions for the development of this document.

Conflicts of interest

The authors declare no conflict of interest.

Data availability

The data collected did not include sensitive or personal data. In accordance with the objectives of this study, there was no need to collect private information that allowed distinguishing people's contributions. Additionally, the statistical treatment was done in an aggregate manner to obtain more general responses. *The data and other aspects related to this research can be consulted at the following* link *for its replication.*

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