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Translating knowledge into innovation capability: An exploratory study investigating the perceptions on distance learning in higher education during the COVID-19 pandemic - the case of Mexico

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ABSTRACT

The COVID-19 pandemic represented a significant challenge to higher education and forced academic institutions worldwide to abruptly shift to remote teaching. Higher education institutions are continuously confronted with the difficulties of creating satisfactory online learning experiences that adhere to the new norms. This paper presents a study concerning the perceptions of the quality and efficiency of the educational process in higher education concerning distance learning at the Instituto Politécnico Nacional of Mexico during the COVID-19 pandemic. The data analysis identified the level of satisfaction with distance learning education separately for students and professors and the lived experience for future education models. Data analysis consisted of a stepwise regression model to identify the most important variables related to the satisfaction aspect of e-learning for students and professors. The main findings are associated with the perception of one's own skills as the most crucial variable to define the aspects of e-learning satisfaction. Therefore, these skills involve the knowledge of e-learning platforms and the adoption rate of new technologies. The study found that the students emphasized that the variable "low sense of community" negatively impacts e-learning due to the loss of personal contact with the academic workspace. The key contribution of our research is a knowledge translation into a sustainable innovation capability model.
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Introduction

The COVID-19 pandemic has created the largest disruption of education systems in history. It affected nearly 1.6 billion learners in more than 190 countries on several continents. The closure of schools and other learning spaces impacted 94% of the world's student population, and up to 99% in low- and lower-middle-income countries.

We were unprepared for disruption on this scale. The lockdown of higher education institutions and other schools at different levels implied a problematic transition to online education. Perhaps Latin American countries faced more issues, from access to mobile computing devices, connectivity issues, lack of digital content aligned with study programs, faculty not prepared for online systems and platforms, and economic problems to include inadequate equipment and internet services.

Avalos-Bravo et al. (2022) argued that Mexico had provided emergency technological and remote provisions instead of distance learning during the pandemic. Although the ad hoc provision of online education certainly had its shortcomings, it is interesting to know to what extent the surveys run by higher education institutions and communities of students confirm that this work worked relatively well and that most students and education personnel were reasonably satisfied.

Mexican higher education institutions face new pressures from the COVID-19 pandemic. Traditional public funding sources are decreasing, and advanced technologies threaten to automate an increasing number of jobs; employers and institutions are rethinking what and how to learn and teach. Thus, a conclusion is becoming clearer. Traditional models of higher education will need to evolve so

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that their impact on economies and societies remains as high in the next six decades as it has been in the past.

The most immediate challenge is how to tackle the COVID-19 postpandemic, which has forced most higher education institutions worldwide to suspend face-to-face teaching and switch to online classes or explore hybrid models. Although this will remain feasible for most courses in the near future, it will be challenging to maintain this approach in the long term. Courses that include practical training, for example, will have difficulty operating if the outbreak reappears. Institutions that depend on international student admission fees will also face financial challenges exacerbated by pressure from students to reduce or partially refund fees. Governments can provide emergency financial support, but some smaller higher education institutions are likely to withdraw, and larger institutions may absorb others.

Domino effects are likely to have a permanent impact on higher education institutions. Students' exposure to online learning increased due to the outbreak, requiring higher education providers to rethink their delivery methods. In the middle of what is likely to be a deep economic recession, students and their families will be concerned about what type of higher education offers the best value. Therefore, online learning has contributed to making education more accessible to more students. However, if an equitable approach that considers a holistic and integrated system is not implemented, it will imply disadvantages to others. Likewise, travel restrictions, mainly for Latin American students and professors, made international collaboration more difficult for education. However, they might also prompt the development of more environmentally sustainable and inclusive research initiatives.

In Mexico, as in other countries, the pandemic undermined the ability of universities and educational staff to do their job of providing high-quality and safe educational environments for their students. Immediate issues and challenges such as campus safety, admission processes, and hybrid education arrangements dominated the discussion. Currently, it is necessary to develop new online learning resources that enrich education models and improve the deficiencies shown in the last academic periods, according to recent experience. Therefore, hybrid models must face problems related to access to laboratory space, equipment, difficulties in recruiting study participants, etc. Spending on education and research is threatened by economic downturns with university budgets squeezed by COVID-19, imperiling jobs and research funding. Recovering research and educational programs after funding and expertise are lost will be an enormous task for the Mexican government.

The COVID-19 crisis has placed multiple aspects of economic and social life in a new context. The imbalances created by globalization, the unequal spread of knowledge and technology, and poverty across countries will become more evident. These aspects have generated a negative effect on higher education. It implies change and transformation in the next period and in the long run. Changes will probably take place in the next period, and they will become the new normal in the higher education sector much more than in the education system as a whole. The higher education system had to manage a very dynamic economic environment and had to face the challenges imposed by its rapid evolution under globalization. Furthermore, higher education systems act in different economic, social, or political environments, and a common strategy for adapting to post-COVID-19 times is challenging to put in place.

Under these circumstances, our objective is to identify the perception of changes in higher education strategies, techniques, and methods and to identify commonly needed solutions for future academic periods. The goal of this paper is to identify the perceptions of the quality and efficiency of the educational process in higher education concerning distance learning in the era of COVID-19. In this context, students and professors of the Instituto Politécnico Nacional of Mexico (IPN) were surveyed to highlight improvements the community needs. In addition, the trends to ensure the feasibility of transforming into a hybrid education model are explored.

The rest of the paper is structured as follows: the next section comprises the literature review on distance learning and its implications on the quality of the educational process, Section 3 describes the methodology, Section 4 investigates the results, and the last section discusses the key findings of our research.

Related work

This section is devoted to describing the state of the art related to distance learning and particularly explores the implications of the quality and satisfaction of the educational process, the impact of the COVID-19 pandemic on education and the perception of distance learning during the COVID-19 pandemic.

Impact of the COVID-19 pandemic on education

The COVID-19 pandemic has changed the approaches to traditional models in education and created the most significant disruption of education systems in world history. All practitioners and educators have evolved their educational methodologies to incorporate information and communication technologies to address the resilience and challenges of online education (d'Orville, 2020; Williamson et al., 2020; Konig et al., 2020; Dimian et al., 2021). Therefore, educational activities suffered a significant impact on teaching techniques at the beginning of the pandemic. Schools and colleges worldwide closed their doors almost overnight, affecting nearly 1.6 billion students in more than 190 countries (UNESCO, 2020). The closing of universities and other learning spaces has affected 94% of the world's student population, and up to 99% in low- and lower-middle-income countries (Rojanaworarit & El Bouzaidi, 2021). This unprecedented situation had cascading consequences in students' lives, whether studying abroad or in their own country.

In 2020, in almost all activities of daily life, the impact of COVID-19 was practically noted, but in the teaching and learning processes, the effects were disruptive. The pandemic has faced traditional education models of higher education institutions around the world with three particular issues: maintaining class teaching with social distancing, generating hybrid education models, or transforming face-to-face classes to online education (Hodges et al., 2020).

Many countries have been forced to replace traditional face-to-face education with distance learning in response to the COVID-19 crisis without necessarily being ready or having sufficient experience. A recent study analyzed the implications of implementing distance learning under cross-cultural variations by analyzing social media posts, online classes, and interviews (Al Lily et al., 2020). The study revealed that the quality of the educational process could be influenced by poor preparedness and incompetence. These aspects are factors related to educational and psychological implications. Moreover, other factors are associated with procedural or logistical ramifications or simply 'staying at home' (*e.g.*, stress, anxiety, among others) that prevent students or professors from learning or teaching.

At this point, the pandemic caused a massive disruption in the traditional education models of the teaching process and the way students are taught. Thus, different study cases have been proposed to analyze this issue. Iglesias-Pradas et al. (2021) studied the move to remote emergency teaching and its organizational impact. The study considered unplanned change, class size, synchronous or asynchronous delivery variables, and the usefulness of digital support technologies. The results showed an increase in the students' academic performance in remote emergency teaching and supported the insight that organizational issues can promote the successful implementation of online models.

Many studies have investigated the perception of distance learning in different countries at the beginning of the transition to distance

learning under the COVID-19 pandemic: Portugal (Goncalves et al., 2020), Morocco (El Firdoussi et al., 2020), worldwide with a focus on Asia (Marek et al., 2021), Poland (Rizun and Strzelecki, 2020), Arab countries (Al Lily et al., 2020; Al Ateeq et al., 2020), China (Wang & Zhao, 2020), and Germany (Konig et al., 2020), among others. Although the pandemic has disrupted normal conditions and daily life in higher education institutions, the learning process has continued under different strategies. Online education based on an e-learning approach was the main initiative, and it recently continues to play the most critical role in providing conventional classroom settings. However, this situation has forced students to learn using this kind of technological tool, and their acceptance is very different according to the knowledge domain. One study examined the instructor and student characteristics and the technology acceptance model regarding the behavior of the students to use and accept online learning (Baber, 2021). All data collected were processed and analyzed using the partial least square structural equation modeling technique, and the results demonstrated a positive influence on the acceptance of learning management systems in South Korea during this pandemic.

Studies associated with student mobility are also interesting to analyze in the context of pandemics. For example, Mok et al. (2021) presented an analysis to examine how students in mainland China and Hong Kong conceived overseas plans against the COVID-19 pandemic. The study analyzed a dataset collected from student responses regarding their perceptions of their interest in significantly applying to academics abroad after the pandemic. The results showed that the pandemic decreased the mobility of international students and displaced the flow of international students. This analysis debates policy implications, suggesting how the global health crisis could increase economic and social disparities across diverse higher education models.

Other experiences, such as the case of India, demonstrated that the education system worldwide was not prepared during the pandemic lockdown period. Mishra et al. (2020) presented a study representing the adoption of the online-learning process at Mizoram University. The analysis described the main requirements of the online teaching-learning process and the digital resources needed to transform education effectively. Additionally, qualitative and quantitative techniques were applied to understand the perceptions of academic personnel and students about online education. In another recent study (Ceesay, 2021), an online survey using statistics, correlation, and multiple regression analysis revealed that work and home education were significantly negative in Africa. The results also demonstrated the lack of technological resources, infrastructure, and computing equipment to continue the activities adequately.

In the same context, Roman & Plopeanu (2021) designed a test to assess the preferred education model and effective online learning among Romanian students in economics. The test was applied considering traditional, online, and hybrid methods. The sample obtained from five faculties of economics was significant. The results demonstrated that psychological issues increased with the COVID-19 pandemic. This situation revealed a negative effect on the effectiveness of online education. The analysis exhibited issues to improve in the short term: deficiency in internet access service, supersaturation with overtime to complete tasks, nonprogramming work schedules, and reduced working spaces. Thus, the online activities of the student population decreased because their perception of remote education was less effective.

The COVID-19 pandemic represented an extraordinary challenge for worldwide educational systems to urgently adapt to distance learning, ensure continuity of the educational process, and maintain its quality. The sudden change forced the fast adaptation of learning tools for lectures, assessment, and research. Dietrich et al. (2020) concluded that many of the existing approaches to education delivery were not suitable currently with generations with fewer time constraints and many sources of distraction and stress. Under new circumstances, the disruption of the educational process should find answers in targeting flexibility toward students, motivation, ethics of student assessment, and lack of access to technology (Qiao et al., 2021; Ashri et al., 2020). According to the above, the response should integrate methodological and technological decisions while ensuring equity and transparency (Garcia-Penalvo et al., 2020).

The 2030 Agenda of the United Nations has already established policies focused on novel methodologies and strategies to transform higher education programs. It is translated into public support for tertiary institutions to defend research and public innovation. It refers to transdisciplinary approaches to tackle complexity and knowledge exchange to seek novel solutions in the context of online education. Initiatives focus on addressing challenges in which universities are on the cutting edge in building innovative education policy-making with the collaboration of other institutions that will impact the transformation of educational initiatives (Väänänen & Pöllänen, 2021).

Alqahtani & Rajkhan (2020) contributed to the discussion on distance education, identifying the critical success factors for e-learning, using two multicriteria decision analysis methods: the analytic hierarchy process and the technique for order preference by similarity to ideal solution. They stated that improving the educational process is highly influenced by technology management, increased student management awareness of e-learning, and the level of information technology demand from all actors involved in the process (students, instructors, and universities).

On the other hand, Darling-Hammond & Hyler (2020) stressed the need to recruit, develop and retain a strong workforce in the education system to ensure both equity-focused and high-quality educational processes. This means being ready to face any combination of traditional learning, such as distance and blended learning. Murray et al. (2020) considered the COVID-19 pandemic a moment of rethinking to develop a new framework of priorities for the educational process. The study proposes a reconceptualization based on the relatedness of interdisciplinary, global, and justice-oriented education. It includes new competencies in the fields of technology, data science, ecology, and others. This should be based on close observation and careful perception of all aspects of distance education and a strong commitment of stakeholders and institutional support. Sheth (2020) discussed the changes in old habits that emerged from technological advances, demographic changes, and innovative ways people have learned to cope with new boundaries of work, education, and leisure during the pandemic. The study highlighted that the boundaries between work and life blur as people work and learn from home. Moreover, they could find it easier to learn from home, breaking new ground in the education process.

Even in prepandemic studies, students' satisfaction with using distance learning was investigated. Sun et al. (2008) found that critical factors for students' perceived satisfaction are computer anxiety, course flexibility and quality, and diversity in assessment. In other relevant studies on distance learning, Al Ateeq et al. (2020) and Wang & Zhao (2020) explored the perceived stress level among students. Concluding that the stress and anxiety levels increased, they suggested integrating stress management programs to mitigate the higher stress during distance learning. Aristovnik et al. (2020) also found increased anxiety, frustration, and boredom concerns. The study concluded that the perception of self-improved performance in the new context was prevented by the perception of increasing workload and a lack of computer skills.

During the COVID-19 pandemic, the effects of personality and stress among students have been considered essential issues to support reasonable performance in online education. Zheng et al. (2020) presented an analytical study to describe the relationship between proactive personality and social media, considering the lack of internet access and the quality of online interaction. The study was carried out by conducting an online survey of students and teachers from

Islamabad, Pakistan. The analysis revealed that the proactive personality of the students encouraged their social capital by employing quality online interactions. In this way, the virtual courses were modified to change perception and improve acceptance.

Higher education institutions had to act quickly to adopt measures to change traditional educational models to a flexible approach. The educational process has gone virtual, moving to digital content. Although many actors involved in the process coped with these changes, others experienced barriers, difficulties due to access to technology and the internet, lack of experience and/or hardware, or lack of available physical space (Beaunoyer et al., 2020; Iivari et al., 2020; Blundell et al., 2020). Fig. 1 shows the relevant factors and challenges of successfully adapting to distance learning based on the literature review.

This global crisis has triggered a rethinking of the delivery of educational services at all levels of education. The intensive use of diverse technology platforms and resources to ensure continuity of learning is the most audacious experiment in educational technology, even unexpected and unplanned. Therefore, we must evaluate the results, better learn what works and why, and use the lessons learned to reinforce inclusion, innovation, and cooperation in higher education. Additionally, there is an urgent need to move toward more collaborative and student-centered models of learning (Perez-Lopez et al., 2021).

Perception of distance learning during the COVID-19 pandemic

Although the COVID-19 pandemic continues to evolve, its effects have decreased due to the vaccination programs in each country. Even under these circumstances, investigations related to the impact of COVID-19 on education continue to emerge.

A holistic view of the participation of students in online learning in the COVID-19 era is presented by Namboodiri (2022). It provides the perspective of stakeholders and offers insights to put into practice during and after the pandemic. According to Namboodiri, engagement is a shared responsibility of stakeholders, which requires moving beyond merely replicating the 'offline' or physical settings toward a combination of being learning-centered and student-centered simultaneously to achieve successful online learning. The investigation argued for the role of technology that will continue to accelerate, eventually making online learning an integral component of higher education. In addition, the contribution highlights the need for effective pedagogical practices and well-designed academic programs. An interesting reflection on the 'new normal' term is presented, with the aim of implementing new perspectives and policies to implement during the postpandemic era. The limitation of this investigation is the lack of statistical analysis of the regions and stakeholders who provided information about their respective institutions.

Stracke et al. (2022) proposed a compilation of thirteen life experiences from policy-makers from different countries related to the perceptions and rapid solutions implemented due to the COVID-19 outbreak. Responses ranged from conservative to radical actions to maintain active educational systems according to the resources and capacities of each country and particularly of every university. The analysis describes the recommendations and best practices performed by each country. Stracke identified particular trends that are similar for all or most countries: (1) face-to-face education at distance for the first time; (2) similar techniques for formal education; (3) lack of ICT infrastructure and sharing of open educational resources; (4) variety of teaching and learning methods and practices; (5) access to open educational resources; (6) urgent need for professional development and training for teachers; and (7) assessment and monitoring of learning environments, teachers, and students. The work is a good narrative on the facts of each university that participated in the proposal; however, statistical analysis to correlate the information to reveal new findings as a part of the study is not presented.

Ndibalema (2022) conducted a systematic review of the limitations and effective transition from face-to-face to distance learning in higher education institutions in developing countries. It consisted of a bibliometric analysis summarizing eleven publications from six scientific databases. The contribution points out three central major issues: (1) blind turning to online distance learning, (2) personal and institutional readiness for online distance learning, and (3) social-emotional challenges due to the transition to online distance learning. Furthermore, two recommendations are made in the transition to online learning programs that are sustainable, such as the need to invest in technology to face personal and institutional technological challenges and the promotion of professors' skills in creating digital solutions to tackle digital equity. The difference with our analytical approach is, based on this study, that Ndibalema did not consider a statistical analysis to present their results. Ndibalema's findings reflect the life experience across different higher education institutions in developing countries, of which the representation may not be sufficient.

Various strategies and innovative solutions based on information technology were developed during the COVID-19 pandemic. Divjak et al. (2022) presented a systematic review of the use of flipped classroom approaches to stimulate student engagement and activate collaborative learning in higher education. The bibliometric analysis showed that students were dissatisfied with online learning, especially with communication with teachers. Moreover, teachers noticed problems with student engagement in online education. However, other studies demonstrated that the combined online teaching model with the flipped classroom improved students' learning, attention, and evaluation of courses. In conclusion, the review describes different case studies, and according to the capacities and financial resources, the perception of implementing flipped classrooms to assist online learning is very subjective. The review needs to be complemented with rigorous analytics to present the tendencies and components that characterize this behavior.

Stecuła & Wolniak (2022) presented an investigation of the influence of the pandemic on disseminating innovative online learning tools in higher education in Poland. The results showed that the percentage of students' skills with e-learning tools increased significantly during the pandemic. In addition, the investigation discovered three categories of e-learning tools used: popular services and applications adopted for online learning, widespread applications for synchronous meetings, and other synchronous and asynchronous e-learning methods. According to their analysis, familiarity with information technology and an interest in innovative tools had a positive effect on the acquisition of digital content in e-learning. This study considered a small sample (n = 186) that in larger samples might not be representative. However, the results on students' perceptions about the information and communication technologies were positive. Another study in a business school in Warsaw, Poland, concerning the perception of online learning was conducted by Szopiński & Bachnik (2022). It explained to what extent the perception of the value of business school education is influenced by student engagement, travel time to the business school, and nationality. The variables considered in the study are related to the evaluation of online tasks, the frequency of participation in online courses, and the preference (face-to-face or online). The sample size was 317 respondents, and data analysis consisted of applying the chi-squared, Kruskal–Wallis, and Mann–Whitney tests. Our proposed approach considered 29 multifaceted items and the design of two multiple regression models for e-learning satisfaction: one for students and another for professors.

Xie et al. (2020) presented a study that demonstrated implications for optimizing and improving the education of students and knowledge acquisition methods in China in the context of the long-term

COVID-19 pandemic. The study consisted of a survey of 2397 Chinese students, finding that COVID-19 information from mainstream Chinese media and overseas media, as well as social media, had a significant promoting effect on the acquisition of online knowledge of students. The study explored the relationship between psychological facts and online knowledge acquisition and revealed the positive impact of mental health on online knowledge acquisition for students. The study presented a theoretical foundation based on statistical and regression analysis, obtaining the following results. (1) The influence of pandemic information from mainstream Chinese media and overseas media on the online knowledge acquisition of students was significantly higher than that of social media. (2) The analysis demonstrated that the impact of pandemic information from mainstream Chinese and overseas media had a significant negative impact on the psychology of students (negative emotions such as irritability and depression). This study is very timely and suitable for the students' perception and fits our proposal considering only the approach. Both investigations performed a deep statistical analysis to reveal findings that higher education institutions' communities have lived during the COVID-19 pandemic.

Similarly, Laili & Nashir (2021) presented a study of higher student perceptions of online learning. The respondents were 103 students from Stikes Banyuwangi in Indonesia. The results showed that 91% of the students preferred face-to-face learning due to the readiness of supporting tools, access to the internet, learning management systems, and motivation. The study applied a qualitative descriptive method, referring to basic statistics. In comparison, our approach proposes regression models to analyze the degree of satisfaction with a convenient sample that reflects the perception of the whole community.

Maatuk et al. (2022) identified issues related to the advantages, disadvantages, and use of online learning at the University of Benghazi, Libya. The study centered on the perceptions of students and teaching staff in the information technology faculty. The descriptive analysis considered four dimensions: the extent of using online learning during the COVID-19 pandemic, drawbacks, benefits, and main obstacles to implementing online learning in the faculty. Statistical analysis showed that students believe that e-learning contributes in a good manner to their education. However, the student workload increases. The findings of the teaching staff demonstrated that e-learning enhances students' skills, although financial investment and implementation costs are higher. Therefore, the r of this research work is similar to the findings obtained in our study. This means that most of the issues concerning online learning mainly affect developing countries.

Salta et al. (2022) presented a statistical analysis based on a multiple regression model to measure the participation and interactions between face-to-face learning and the online education environment. The study was conducted using data from two Greek universities, with a sample of 360 respondents. The analysis demonstrated that academic performance decreased, and emotional involvement was the reason for the low level of human interaction. Data analysis explored the following variables: institution, academic major, and study semester. In contrast, the analysis performed in our proposal uses two different multifaceted regression models to evaluate and correlate both students' and academic staff perceptions.

On the other hand, Azhari & Fajri (2021) explored the online learning process of teachers from different schools in Indonesia during the lockdown of educational institutions due to the COVID-19 pandemic. Data were collected using a questionnaire from 353 teachers and six interviews. The main issues discovered by the data analysis referred to problems with the implementation of learning management systems, limited internet connectivity, and the inability to exploit technological resources. The study determined which applications were the most widely used in distance learning. The findings are associated with clear technical guidelines and instructions for the academic staff in implementing distance learning. The research method was centered on two main variables: applications in distance learning and the use of online learning websites. Our approach uses 29 multifaceted variables distributed in two regression models to explore the perception of students and teachers on distance learning, providing more accuracy and certainty to the analysis.

In Canada, a study was carried out to measure the online learning satisfaction of students in a major university in the country. It adopted a mixed-method designed to understand the factors that affect students, considering five variables with 14 possible answers and applying extant scales (Conrad et al., 2022). According to the data analysis, the students' experience was negative. It was affected mainly by information overload and perceived technical skill requirements. Thus, qualitative evidence suggests that lack of social interactions, class format, and ambiguous communication also affected perceived learning. Regarding our approach, the sample collected is more significant than that of the Canadian university, which analyzed only 240 complete responses. It is difficult to argue that size is appropriate in perceptions of online learning satisfaction and the factors involved in these perceptions.

Another study on the student perception of Nigerian institutions on satisfaction with online learning is described by Egielewa et al. (2022). The study used 1134 Nigerian students from three types of higher institutions. A quantitative survey method was proposed to analyze the collected data to show that students were not satisfied with virtual education. The main issues discovered by the analysis were the following: low internet connectivity and infrastructure, lack of electricity, and, in some cases, high energy consumption. This study is similar to our approach, but the sample size that we collected is larger. Furthermore, we proposed regression models for the perception data analysis, and satisfaction was associated with all variables in the case study.

The field of education was severely affected by the COVID-19 pandemic. However, medical higher education institutions were one of the most damaged academic programs in universities. The medical and health schools did not prepare for this disruption. Therefore, the sudden change generated different problems for students and professors at the moment to transform the face-to-face teaching-learning processes to distance education. Baticulon et al. (2021) identified the main barriers to virtual learning in the medical field. The study consisted of analyzing the feelings of medical students from the Philippines. The data analysis considered demographics, medical school information, access to technological resources, study habits, living conditions, self-assessment capacity, limitations to online learning, and proposed intervention variables. The results based on the respondents showed the main barriers to online education in medical schools in the Philippines: difficulty in adjusting learning strategies, implementation of student-centered interventions and lack of training in technological resources. Consequently, our approach addressed the analysis of the perception concerning the satisfaction of online learning, designing two regression models for the analysis. In contrast, this proposal only focused on medical students, in which the analysis was classified into five categories using the Kruskal–Wallis test.

In other fields, such as engineering schools, the impact and implications were very different. Ahmed & Opoku (2022) examined the challenges faced by engineering students and academics of the College of Engineering at a higher education institution in the United Arab Emirates. Therefore, a dataset composed of surveys and interviews was collected. Subsequently, statistical techniques were also applied to identify students' perceptions. The study revealed that, compared to other knowledge fields, engineering students well assimilated the use of technology to support learning, enhancing the learning process experiences. Our study covered four knowledge fields according to the academic programs offered by the IPN. Thus,

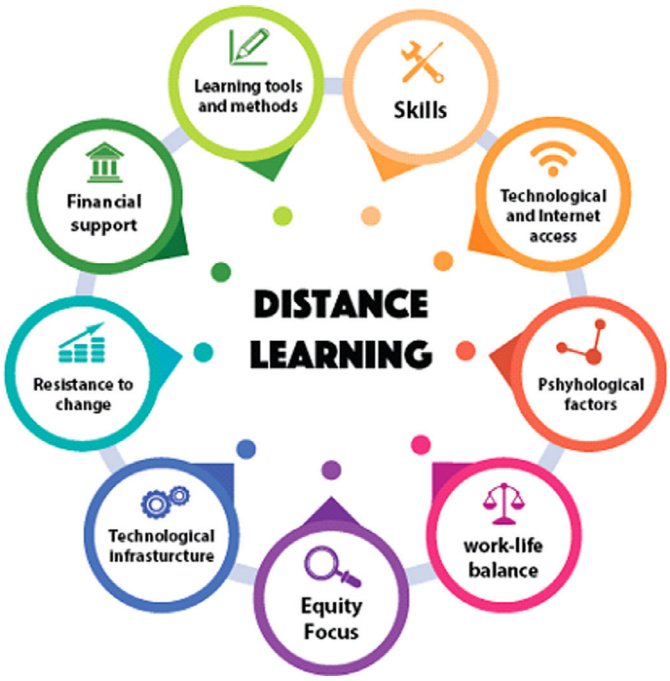

Fig. 1. Distance learning: factors and challenges

the data analysis spread the variables to better correlate with all the academic fields.

Regarding the case of sports and physical education, there is very little evidence on the use and outcomes of the application of digital technologies. Moustakas & Robrade (2022) presented a study to describe how e-learning technologies and pedagogical approaches were used in the sports field. According to their statistical analysis, the results showed that variety and interaction were critical factors of success in the learning-teaching process. The main problems reported during the COVID-19 crisis were the following: student motivation, the 'real' practice with a social nature, and the connection between students and professors. The study discussed the lack of technological innovation, where many tasks did not fully translate to online learning.

In a study concerning the transition to e-learning during the COVID-19 pandemic, Turnbull et al. (2021) stressed that the forced transition to online learning as the only viable solution in a pandemic context faced many challenges, e.g., the integration of synchronous and asynchronous learning tools, technological endowment, and online competences both for students and faculty. They concluded that ongoing investments were significant for maintaining high-quality higher education programs. In the same vein, Mukhtar et al. (2020) considered that the COVID-19 pandemic evolved institutions to increase investment in the delivery of online learning, provide access to education for all, and overcome many limitations.

According to the state of the art, our reflection suggests that it is time for higher education to design new strategies, new futures, and flexible ways of responding to fast changes and unstable environments. Therefore, innovations in higher education methods seem to be the result of the need to respond to new issues added to the others we already had: consequences of globalization, unequal access to technological development, demographic and environmental crises, and inequalities, among others (see Table 1).

Personal satisfaction at work and student satisfaction should ensure new creative teaching models that employ novel information and communication technologies. The transition from face-to-face learning to distance learning was made almost overnight. This shift created space for innovation in distance learning and the future use of hybrid learning. Continuing intention to implement e-learning was investigated even before the pandemic by Lee (2010), who found that satisfaction and perceived usefulness are relevant factors of individuals' intentions to continue using e-learning. More recently, Xiao et al. (2020) and Marek et al. (2021) discovered that satisfaction and experience are indicators for evaluating this process.

According to the state of the art, the present work was intended to identify the perceptions of the quality and efficiency of the educational process in higher education with respect to distance learning during the COVID-19 pandemic at the Instituto Politécnico Nacional of Mexico. The main contribution focuses on the representative data analysis because the stepwise regression model correlated the perceptions of students and professors. Therefore, the findings present adequate certainty regarding the variables analyzed to recreate the sense of e-learning. Furthermore, the study revealed that the skills immersed in the knowledge of technological resources represent a negative impact of e-learning. The novelty of this study relates the translation of knowledge into a model of sustainable innovation capability for future education initiatives and policies for higher education institutions.

The research methodology

The research approach consisted of evaluating distance learning during COVID-19 times (2020-2021) regarding perceptions of the quality/efficiency of educational purposes in a higher education environment for both students and members of academic staff. Data were collected from the Instituto Politécnico Nacional of Mexico (IPN), the second largest higher institution in Mexico, having 100,854 undergraduate students and 17,534 academic staff members, covering four knowledge fields: Life Sciences and Medicine, Engineering and Technology, Social Sciences and Management, and Library and Information Management. After obtaining the necessary permission from the university, an electronic questionnaire was sent via email to a sample of 5000 undergraduate students and 875 members of academic staff (professors), representing a percentage of 5% of the total population (at the undergraduate level).

As shown in the previous section, we performed an extensive literature review to investigate the relevant aspects in terms of perception of distance learning during the COVID-19 pandemic. Our questionnaire, designed after the evaluation of the relevant theoretical literature, includes questions for students and professors regarding their perception of quality and equity of the educational process, perception of their own skills, personal satisfaction in work, sense of community, student satisfaction, financial resources, technological endowment, and organizational policy.

The sample of students was selected randomly by applying the RANDBETWEEN function in MS EXCEL to an anonymous email list of all students and academic staff. Later, the questionnaire link was sent to the randomly selected sample by email. The final sample size consisted of 4044 cases, of which 3201 (79.2%) were students (response rate 64.02%) and 843 (20.8%) were professors (response rate 96%). The questionnaire contained 29 multifaceted items with questions derived from the literature review. Most of the questions are based on a 5-point Likert scale.

Additionally, there were multiple response questions regarding the efficacy of e-Learning methods and a question on 1-100 regarding total satisfaction with the e-Learning education. Fig. 2 summarizes the questions designed for the survey.

Our **first research question** was to locate the important aspects of the e-learning process. For this purpose, we use descriptive statistics.

Our **second research** question was to explore whether there were differences in the overall e-learning evaluation between students and professors. For this purpose, the independent sample t test procedure was employed to analyze the answers.

Our **third research** question was to test whether there were differences between students and professors in the variables involved

Table 1
Literature review on distance learning during the COVID-19 pandemic – An overview.

Related work	Key contribution	Our proposed study - variable
Darling-Hammond & Hyler (2020)	The authors highlighted the importance of engaging in distance learning productively as any other type of traditional or hybrid education, including an equity focus to address the academic and emotional needs of students.	**The quality and equity** of the educational process - We investigated the immediate impact of the pandemic on learning in terms of continuity of the learning process using distance learning methods. A critical factor the perceived satisfaction of students is the quality of the educational process. Regardless of how it is delivered, the educational process should ensure both equity-focused and high-quality educational processes.
Aristovnik et al. (2020), Murray et al. (2020)	The authors found that people experienced boredom, frustration, anxiety, and increased stress derived from the transition to distance learning. These factors correlated with others, such as the perception of increased workload and deficient computer skills, prevented them from perceiving their improved performance in distance learning. They considered vulnerability and uncertainty in response to the COVID-19 pandemic as an opportunity for growth in distance learning. They underlined the need for globally informed and responsible education programs requiring new technologies and data science competencies. They underlined the need for globally informed and responsible education programs requiring new competencies in technology, data science ecology, etc.	**Human resources - perception ff skills - In our recommendation, the perception of own skills is the core variable that defines e-learning satisfaction for** students and professors. Our proposal investigated the satisfaction with the e-learning support as a dependent variable in correlation with the human resources and skills.
Salta et al. (2022)	The authors compared the engagement and interaction in traditional and distance learning and concluded that low personal satisfaction was the reason for the decrease in perceived academic performance. The transition to distance learning required new teaching methods and changes in assignments and exams, while students' expected volume of work decreased.	**Personal satisfaction in work** – Our research focused on investigating the perceived appreciation of others, responsibility for good results, and appreciation of others. We stressed the importance of new learning and teaching tools, particularly bold on active tools.
Conrad et al. (2022)	Online learning satisfaction is affected by lack of social interactions, class format, and ambiguous communication.	**Sense of community** – In our analysis, we investigated the sense of community when using distance learning in terms of trust, personal connection with colleagues and the academic community, and perception of social isolation.
Azhari & Fajri (2021), Alqahtani & Rajkhan (2020)	These studies recognized the practical implications of e-learning during the COVID-19 pandemic. They found that the readiness for implementation of e-learning and the use of technological resources played a crucial role in the expansion of the educational process. In this case, there were evaluated aspects such as technology management, student awareness of the use of e-learning systems, and the demand for information technology for all involved actors.	**Technological endowment** - We analyzed the impact of technology integration on learning outcomes in the context of the temporal closures of face-to-face activities on the campuses.
Dietrich et al. (2020), Egielewa et al. (2022)	The authors studied the new distance learning tools used when the pandemic disrupted the traditional educational model. They concluded that special attention should be given to hybrid education in the future, which will require time and investment to ensure flexibility toward students, motivation, ethics of student assessments, and access to technology.	**Student satisfaction -** Our analysis focused on the satisfaction of the e-learning support as directly correlated with the organization's policy (which refers to the university's support in the e-learning processes).
Turnbull et al. (2021) Mukhtar et al. (2020)	These studies highlighted the need for ongoing investments to support the forced transition to distance learning to maintain higher education quality and provide access to education for all participants.	**Financial resources** – In our research, we focused on evaluating the impact of public funding, investments, and decreased revenues due to a drop in enrollment of international students on the quality of the educational process.
Sheth (2020), Baticulon et al. (2021)	These studies showed that technological advances and responses to the COVID-19 pandemic blurred the boundaries between home, education, or work. New technologies facilitating work, education, or consumption will be adopted. Moreover, implementing student-centered interventions and training to use technologies and software is of great importance.	**Organization policy -** In our research, we analyzed the influence of organizational policy on e-learning satisfaction in promoting and supporting e-learning education (providing clear instructions, specialized software, clear obligations, and designing a long-term strategy).

in the evaluation of e-learning. Therefore, the stepwise regression method was applied to locate the most important variables related to professors' and students' satisfaction. The stepwise regression procedure excludes the nonstatistically significant independent variables from the final model. Thus, we created two multiple regression models for e-Learning satisfaction: one for students and another for professors. Statistical analysis was developed using IBM SPSS (Statistical Package for Social Science) Statistics V20 software.

Relevant findings

In the case of the student multiple regression model, the most immediate impact was the temporary closure of face-to-face university activities. The impact involved their daily lives, economic issues, financial burdens, and the continuity of their learning and international mobility. This situation left them in a new environment without a clear idea of how long it would last.

Fig. 2. Educational processes that interact with distance learning (questionnaire items).

In addition, in the case of the teaching staff regression model, we discovered that professors have also suffered terrible effects in their workplace. First, not all IPN campuses had complete strategies for the online continuity of the teaching activity, and consequently, temporary contracts may be finalized. On the other hand, the most evident impact on professors was the expectation and not the demand for continuity of the teaching activity under the virtual modality. Administrative staff represented the most vulnerable sector in terms of the possible reduction in job numbers. The main consequence was the imminent reduction in the university budget. Therefore, some administrative activities were delegated to teachers, which affected the quality of the teaching-learning process.

Concerning the learning/teaching modes that were applied during the period of the pandemic in addition to traditional classroom-based teaching (57.4%), the methods of active learning strategies and synchronous learning covered a significant part of the teaching methods

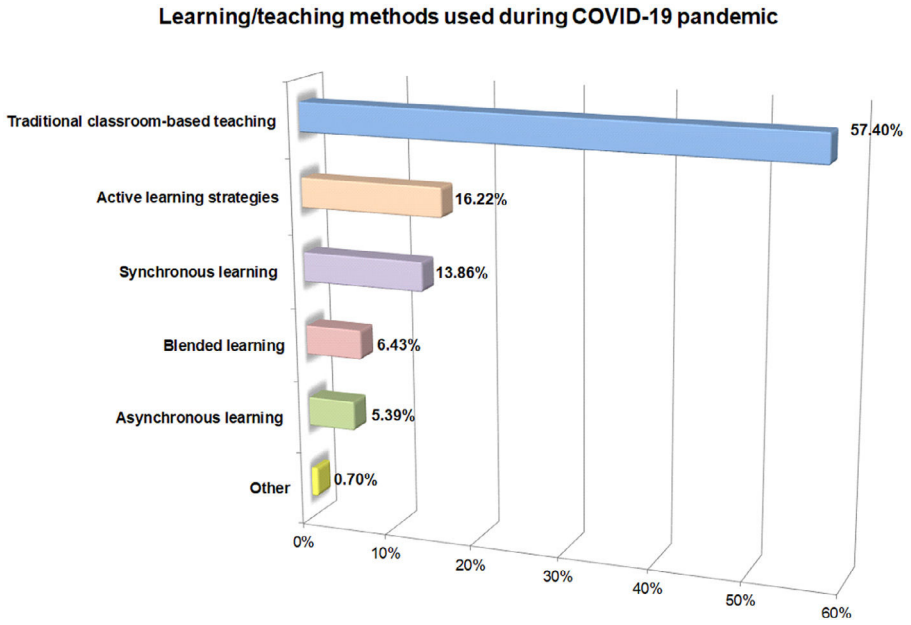

Fig. 3. Learning/teaching modes used for classes during COVID-19**Source**: authors' own.

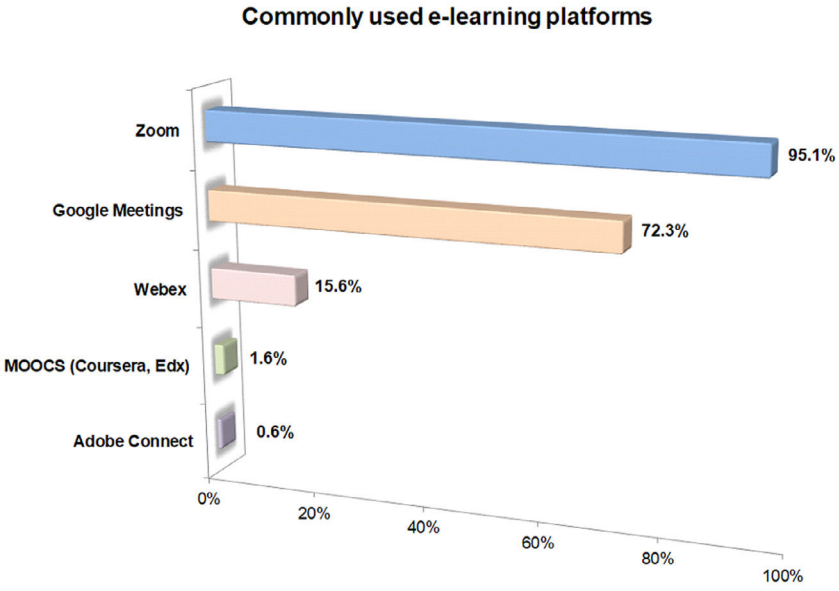

Fig. 4. Used e-learning platform**Source**: authors' own.

used (16.2% and 13.9%, respectively). The results are presented in Fig. 3.

Furthermore, in a multiple response question concerning the main e-learning platform used for classes, most of the respondents selected the Zoom platform (95.1%), followed by Google Meetings (72.3%) and Webex (15.6%). The results are presented in Fig. 4.

Regarding the **first research question** about evaluating the aspects of e-learning, most of the respondents (58.4%) agreed that the integration of technology into learning had a positive impact on the learning outcome. The second most important item was the implementation of active learning strategies (53%) (see Table 2).

The temporary closure of face-to-face activities on IPN campuses has been different. Campuses with education programs focused on engineering and technology were completely adapted to online education, and technological advances served as a novel disruptive feature for their increase. In contrast, campuses with social education programs have suffered from a lack of training in platforms, learning management systems, and other information and communication technologies.

Furthermore, approximately 30% of the respondents reported that they felt comfortable using the various e-learning tools, while 25% were not satisfied. Most respondents (45% feel) feel neither comfortable nor uncomfortable about using e-learning tools.

Concerning the overall satisfaction with learning quality/efficiency during the COVID-19 pandemic, the questionnaire included an item the respondents had to grade between 1 and 100. The mean "satisfaction" was 61.02/100, and the standard deviation was 23.01 (see Table 3). We tested the mean "satisfaction" difference between students and professors regarding the **second research question** using the independent samples *t* test procedure. We noticed a statistically significant difference at the 99.9% significance level (sig=.000<0.001). Specifically, professors are more satisfied than students. Therefore, we reject the null hypothesis that the overall satisfaction of e-learning quality/efficiency is the same between students and professors.

Table 2
The efficiency of e-learning aspects (by order of importance).

Which of the following aspects of e-learning worked effectively (multiple responses)	Responses N	Percent of Cases (%)
Technology integration to learning	1913	58.4
Implementation of Active Learning Strategies	1738	53.0
Online assessment	1274	38.9
Provision of educational feedback	994	30.3
Research integration to learning	902	27.5
Delivery of online tests	898	27.4
Provision of rich Educational Content	858	26.2
Knowledge Delivery	817	24.9

Source: authors' own computation

Table 3
Satisfaction with e-learning quality/efficiency (max = 100).

	Mean	N	Std. Deviation
Professor	73.05	843	20.02
Student	57.85	3201	22.71
Total	61.02	4044	23.01

Source: authors' own computation

According to the 9 multifaceted processes presented in Fig. 2 and following the descriptive analysis, the responses to the relevant questions (graded from 1 to 5) were processed separately for students and professors, as shown in Table 4. The questions were reverse coded where appropriate to follow the same direction. These items are presented in Fig. 5 and sorted in order of importance according to students.

Concerning the **third research question**, to better understand which processes impact the satisfaction of students and professors concerning e-learning, we applied the stepwise regression procedure. Two separate models were created, one for professors and one for students (Tables 5–8). The overall adequacy of the regression model for professors is presented in Table 5.

The regression model is statistically significant and explains 28.3% of the dependent variable (satisfaction with e-learning support). The model in its generic form is Professors E-learning satisfaction = 7.067 + 4.75 (quality of education) + 5.44 (human resources) + 5.15 (personal satisfaction at work) - 3.32 (lack of financial resources) + 8.73 (organization policy).

Taking into account the standardized coefficients column, the organization policy variable is the most important to the e-learning satisfaction of professors, followed by the perception of the human resources available from their own skills. Furthermore, the 'lack of financial resources' variable is negatively correlated with professors' e-learning satisfaction, as shown in Table 6.

Table 4
E-learning educational processes evaluation (max = 5, min = 1).

	Which is your profile?	N	Mean	Std. Deviation	Mean Difference (1)-(2)	Sig.
Quality of Education	(1) Professor	707	2.74	.53	.059	.007
	(2) Student	2570	2.68	.46		
Human resources - perception of own skills	(1) Professor	678	3.38	.67	.311	.000
	(2) Student	2485	3.07	.60		
Personal satisfaction in work	(1) Professor	654	3.25	.57	.315	.000
	(2) Student	2419	2.93	.47		
Low sense of community at work	(1) Professor	654	3.22	.90	-.283	.000
	(2) Student	2419	3.51	.75		
Student satisfaction/interaction	(1) Professor	654	2.86	.60	.078	.002
	(2) Student	2419	2.79	.49		
Equity	(1) Professor	650	3.66	.87	.252	.000
	(2) Student	2396	3.41	.74		
Lack of Financial resources	(1) Professor	650	3.51	.71	-.019	.523
	(2) Student	2396	3.53	.67		
Access to technology and adequate software, information	(1) Professor	645	3.36	.61	.080	.002
	(2) Student	2378	3.28	.53		
Organization policy	(1) Professor	641	3.39	.69	.046	.120
	(2) Student	2354	3.34	.59		

Source: authors' own computation

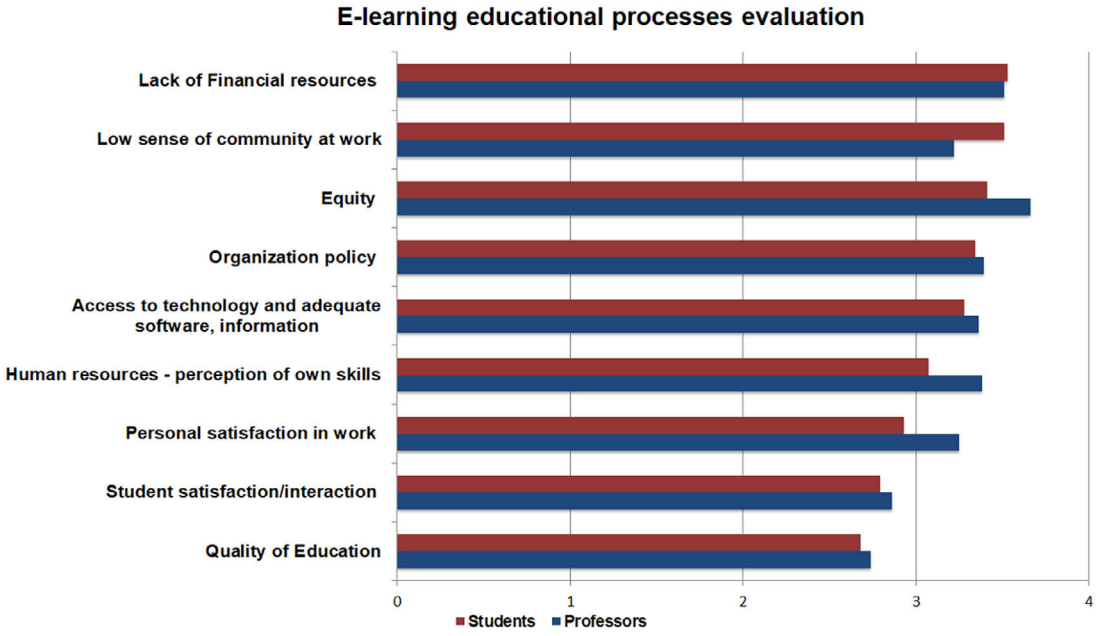

Fig. 5. E-learning educational processes evaluation (sorted by the highest mean, according to students).**Source**: authors' own.

The characteristics of the regression model for the students are presented in Table 7.

The regression model is statistically significant and explains 22.5% of the dependent variable (satisfaction with e-learning support). The model in its generic form is as follows: Students E-learning satisfaction = -14.12 + 7.28 human resources) + 6.02 (personal satisfaction at work) -1.63 (low sense of community) + 2.47 (student satisfaction) + 3.14 (equity) - 2.18 (lack of financial resources) + 4.12 (access to technology) + 4.67 (organization policy) (see Table 8).

Table 5
Regression model fit of e-learning satisfaction for professors.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.537[a]	0.289	0.283	16.877

a. Predictors: (Constant). Organization policy. Lack of financial resources. Quality of Education. Human resources - perception of own skills. Personal satisfaction at work.
Source: authors' own computation

Thus, in the column of standardized coefficients (beta), the variable of human resources-perceptions of own skills is the most important for e-learning satisfaction of students, followed by personal satisfaction at work. Furthermore, the variables 'lack of financial resources' and 'low sense of community at work' are negatively correlated with students' e-learning satisfaction.

In summary, the regression analysis of the perception of one's own skills is a particularly important variable that defines e-learning satisfaction for both students and professors. These skills involve the knowledge of the e-learning platforms and the adoption rate of new technology.

Furthermore, the students seem to focus on the variable of "low sense of community," which is a negative impact of e-learning due to the loss of personal contact with the academic workspace.

In addition, both students and professors emphasize the organization's policy. This includes issues such as university support of the e-learning processes and promoting and supporting e-learning education.

Table 6
Regression model coefficients of e-learning satisfaction for professors.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.067	6.294		1.123	.262
	Quality of Education	4.747	1.433	.129	3.312	.001
	Human resources - perception of own skills	5.436	1.167	.182	4.659	.000
	Personal satisfaction in work	5.146	1.416	.146	3.633	.000
	Lack of Financial resources	-3.317	.994	-.116	-3.337	.001
	Organization policy	8.731	1.025	.300	8.515	.000

a. Dependent Variable: From 1 to 100, how much are you satisfied of the e-learning support in the COVID-19 pandemic?
Source: authors' own computation

Table 7
Regression model coefficients of e-learning satisfaction for higher education students.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.477[a]	0.228	0.225	19.276

a. Predictors: (Constant). Organization policy. Student satisfaction/interaction. Human resources - perception of own skills. Lack of financial resources. Personal satisfaction at work. Equity. Low sense of community at work. Access to technology and adequate software. Information.
Source: authors' own computation.

Discussion and conclusions

The COVID-19 pandemic has posed a significant challenge to higher education and forced academic institutions worldwide to abruptly shift to remote teaching. Due to the emerging transition, higher education institutions continuously face difficulties creating satisfactory online learning experiences that adhere to the new norms.

The consequences of globalization, unequal access to technological development, demographic and environmental crises, and inequalities are essential issues to be analyzed in future case studies related to face-to-face and distance approaches to education. Innovation in higher education methods appears to be the path to creating new education models and policies to address marginalized groups by poverty, gender equality, and environments where access to information and communication technologies is not the same.

Considering the state-of-the-art analysis, the issues and challenges presented during the COVID-19 pandemic in higher education institutions around the world are aligned to the same themes and impacts. The studies converge on the same factors. However, the importance of how they were treated and solved inspires the creation and dissemination of sustainable education models for future global emergencies.

According to the results, we concluded that almost all reviewed studies reported many weaknesses in accessibility to reliable internet service. Moreover, we noticed that innovation in new virtual learning environments and their appropriate disseminations will increase knowledge among professors and students on online research and the accessibility of digital resources during the COVID-19 postpandemic, creating a new beginning for pedagogical transformation in this digital era. Furthermore, we perceived limitations and a gap regarding the scope and support levels that have become highly visible, especially in the most vulnerable groups that must be addressed urgently to reduce educational disparity.

According to the results of the IPN survey, the suspension of face-to-face classes at all levels has given rise to three main areas of action: (1) the deployment of distance learning modalities through a variety of formats and platforms (with or without the use of technology); (2) the support and mobilization of educational personnel and communities; and (3) the concern for the health and overall well-being of students.

The results of the application of this survey have contributed to the adjustment of academic calendars, research proposals to mitigate the impact of the pandemic among members of our community and the country, improved technological planning to guarantee the educational and research activities employing online education throughout the IPN, support of bibliographic and technological resources for the professors and students of each campus, and socioemotional support and care to the community.

It is necessary to review current regulatory frameworks and policies to ensure structural measures that understand education as a continuum where educational trajectories must be strengthened from early childhood to higher education and beyond, thus minimizing the fragility of the most vulnerable students reaching higher education.

The analysis concluded the relevance of carrying out preparation in time for the reopening of face-to-face classes or employing a hybrid education model. Consequently, it will avoid precipitous action and offer clarity in communication to the entire community from the first-moment to guarantee their safety with strict health

Table 8
Regression model coefficients of e-learning satisfaction for students.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-14.119	5.313		-2.657	.008
	Human resources - perception of own skills	7.277	.773	.199	9.420	.000
	Personal satisfaction in work	6.016	1.038	.129	5.798	.000
	Low sense of community at work	-1.628	.716	-.056	-2.272	.023
	Student satisfaction/interaction	2.469	1.011	.055	2.442	.015
	Equity	3.138	.677	.106	4.635	.000
	Lack of Financial resources	-2.183	.761	-.066	-2.869	.004
	Access to technology and adequate software. information	4.118	1.079	.099	3.815	.000
	Organization policy	4.666	.927	.126	5.033	.000

a. Dependent Variable: From 1 to 100, how much are you satisfied of the e-learning support in the COVID-19 pandemic?
Source: authors' own computation

protocols. Thus, academics, administrators, service personnel, and students can be involved in the new context, knowing in advance the provisions, processes, and mechanisms designed to return to academic activities.

Academic authorities must rethink the design of pedagogical measures to formally evaluate and generate mechanisms to support the learning of disadvantaged students, considering future crises and documenting the pedagogical changes introduced and their impacts.

In addition, the IPN authorities have learned from the mistakes and continuously moved toward a digitization program, hybrid models of education, and ubiquitous learning, promoting internal reflection on the renewal of the teaching-learning model.

The effects of the crisis on higher education are easily documented. However, those that will leave their mark on the different members of the community in the medium and long term should be discussed. The lack of references to similar crises in the past makes it difficult to predict and understand what might happen in the immediate future.

In the present work, we used a sample of 4044 e-learning users in a higher education setting (3201 students and 843 professors) to explore the essential positive aspects of e-learning and to assess the differences between the opinions of students and professors regarding e-learning. More than half of the respondents agreed that the integration of technology into learning and the implementation of active learning strategies were essential benefits that e-learning offers. Furthermore, by using regression analysis, we found that the most important item related to e-learning satisfaction, according to professors, is organization policy. On the other hand, the most essential item, according to the students, was the perception of own skills. Additionally, both professors and students agreed that perceptions of their own skills and personal satisfaction at work are important items of e-learning satisfaction.

Although the spirit of online learning is not a clear process of social interaction, constructiveness, regulation, and reflection, it can assist students in maintaining their physical and mental health by reducing their cognitive aspects and strengthening their learning concentration, self-planning, and self-management. We believe that the digital transformation of higher education institutions should aim at the 'next normal,' leaving behind the COVID-19 pandemic and all strategies developed in the 'new normal.' There is no way to return to and continue with the same initiatives in education. Therefore, the 'next normal' should be focused on resilience, sustainability, change, and scaling up the digital transformation to ensure personal, inclusive, and accessible learning and teaching for all where no one is left behind. As further recommendations to move quickly to the digital transformation of higher education institutions to the 'next normal' in the near future, we have the following.

- Supply of active and innovative policies to support open educational practices that involve face-to-face, online, and hybrid learning to increase the students' coverage, including marginal groups.
- Improve awareness of open educational practices with more digital resources that meet pedagogical criteria and an approach to the audience.
- Provide a more feasible ICT infrastructure to improve and cultivate digital skills in the community and ensure internet accessibility. This particular event will impact the quality of education in a short time, reflecting this result in the rankings of international universities.
- Adopt and maintain the practice of open access publications. Policy-makers should issue a directive for all publicly funded teaching and learning resources to be openly licensed for education.
- Motivate and encourage research and development in open education and open science with innovative approaches such as data science, artificial intelligence, the Internet of Everything, and 5G mobile networks to improve applications, methodologies, and tools in online education.
- Reduce cognitive load and cultivate computational and intelligent thinking by using new methodologies and novel approaches to stimulate students to follow online or hybrid learning.

The focus of this study is not oriented toward describing how to overcome other research; it is addressed to show the findings that affected the COVID-19 crisis, particularly in the educational environment, and to share these results to complement other studies that could improve the analysis in different universities worldwide. The research methodology differs from the state-of-the-art because the data analysis consists of two regression models where student and professor variables are correlated to find trends to reflect the perception of satisfaction with distance learning. Moreover, the sample data are robust in comparison with other research studies. The level of certainty is higher in our approach, considering the previous findings. On the other hand, this study is intended to achieve a sustainable education with a goal of improving the quality of educational programs and involving whole communities to remove the technological and pedagogical barriers and contribute as much as possible to achieving equity, flexibility, and more coverage of education toward society.

In another critical direction, it is crucial to interpret the key findings of our research from a Knowledge Translation point of view. Academic institutions play a vital role in knowledge dissemination and contribute significantly to innovation capability at the local and global levels.

The COVID-19 pandemic and the studies that justify research findings such as ours highlight the necessity to build upon empirical findings and link knowledge and learning management in the academic context to sustainable innovation capability. In Fig. 6, we summarize and synthesize the key findings of our research, and we try a generalization of conclusions in the context of knowledge and innovation management.

The delivery of e-learning during the COVID-19 pandemic is an open challenge to interpret the phenomenon as a "Digital Transformation" in a crisis case. The need to set up organizational and digital procedures for delivering knowledge and learning requires a deep understanding of four core components, including e-learning satisfaction, personal satisfaction with the new model, the sense of physical community, and the required strategy.

The second critical component is related to "resources," including human, technological and organizational resources. The availability of resources and their use allows a fertile ground for the experience of digital transformation to be fully supported and implemented. Any lack of these resources disturbs the sustainability of the approach and limits the impact of the digital transformation initiative. Finally, the "Knowledge and Innovation" component highlights the need to use skills and competencies to deliver knowledge and facilitate sustainable innovation.

The introduction of this model establishes a challenge for future research. In our investigation design and in parallel with our effort to analyze and document the experience of students and professors in the delivery of e-learning during COVID-19, we deployed a complementary research tool (digital questionnaire). The key objective was to investigate in five countries, namely, Mexico, Romania, Saudi Arabia, Greece, and Spain, how academics and students perceive the fundamental component of this model as critical enablers of knowledge translation. Given this opportunity, we would like to highlight some future research directions based on the key findings of our research study.

Sense of Community: The development of innovation capability requires a sophisticated approach to designing and implementing digital collaborative spaces where distributed processing will contribute to the delivery of the actual work. Within this context, it is

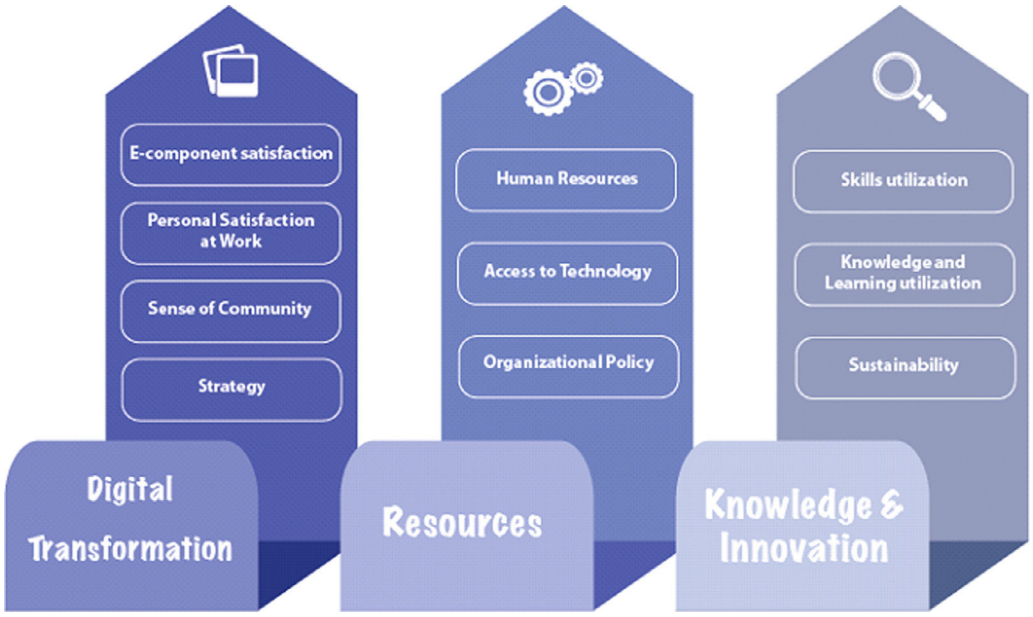

Fig. 6. Translating knowledge into an innovation capability model**Source**: authors' own.

necessary to investigate the essential aspects of the human factors that justify the sense of community and belonging for the human actors of the sociotechnical systems in the context of Digital Transformation.

Access to Technology: The technological component of digital transformation and its connection to sustainable innovation capability raises many questions about marginal cases where this access is not guaranteed. In times of crisis and cases of extreme technology unavailability, we need to design and implement offline recovery systems or response strategies. This is another significant area of future research.

Innovation Capability: The deployment of e-learning during COVID-19 also highlights the need to deploy active learning strategies and new technology-enhanced didactical approaches for the engagement and utilization of skills and competencies of students. A significant future research direction is related to the investigation of meaningful technology-enhanced active learning strategies to promote innovation capability.

Organization Strategy for Knowledge Translation: Our study also contributed to understanding the organizational requirement for the efficiency of the deployment of e-learning methods as a response to the transition of the knowledge and learning delivery mode in times of pandemic crisis. One of the lessons learned is connecting the organizational strategy to impact and sustainability. We must conduct future research in this direction to investigate the modes and ways of strategizing knowledge translation into meaningful innovation capability-building scenarios.

The motivation for this study is aligned with the search for new methodologies to encourage stakeholders to design novel strategies and policies, where the education process relies on different alternatives to confront the challenges that a new generation of students and educators can handle for the future. These efforts require an increase in higher education institutions' budgets, including a higher percentage assignment of the gross domestic product (GDP) in education by the governments. At least, the experience of the Mexican education community demonstrated the lack of resources to improve infrastructures and capacities in the education context. Our study findings showed that the perception of the distance learning-teaching processes reflects the need to think about how to tackle the issues revealed in the analysis and provide useful information to elaborate guidelines for improving stakeholders' decision-making.

We must combine efforts to learn from each other's experiences and collectively act to create a resilient future for education. Postpandemic higher education will be judged using a new scale of values, including technology, equity, mobility, flexibility, international strategies, new teaching methods, links to communities, etc. New approaches should be realistic and flexible to deal with the high complexity of significantly different environments. Moreover, the labor market changes from a knowledge society already implied new demands for the evolution of education in a highly globalized world. The COVID-19 crisis is an opportunity to change in this sector that needs reconstruction on a sustainable basis aligned with the development of technology and knowledge. Therefore, changes at the institutional level are required to consider administrative, investment, and technology issues to turn the crisis into a long-term opportunity for higher education institutions.

Our future work is oriented toward disseminating as soon as possible the key findings of the second part of this research that provide additional insights into the phenomenon of the Knowledge Translation into Innovation Capabilities, employing the case of e-learning delivery in higher education in time of the COVID-19 pandemic. Furthermore, we discovered a difference in the perceived e-learning experience between professors and students since students put the highest priority on their perceptions of their skills and professors put a high priority on organizational policy. Therefore, these two variables are of great interest in future research to verify whether they apply to different higher education institutions. Finally, we feel the need to thank all the participants in our survey.

Author contribution

All authors contributed equally to this paper.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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