# Ibero-american model for technology transfer between public universities through digital technology

## *Modelo iberoamericano de transferencia de tecnología entre universidades públicas a través de tecnologías digitales*

## *Modelo ibero-americano de transferência de tecnologia entre universidades públicas por intermédio de tecnologias digitais*

Luan Carlos Santos Silva [1] https://orcid.org/0000-0002-8846-2511
José Luís Solleiro [2] https://orcid.org/0000-0001-8969-0244
Isabel Álvarez [3] https://orcid.org/0000-0003-2016-0514
*[1] Universidade Federal da Grande Dourados (UFGD), Brasil; [2] Universidad Nacional Autónoma de México (UNAM), México; [3] Universidad Complutense de Madrid (UCM), España.*

Abstract. Technology transfer through digital technologies has emerged as a critical theme during the COVID-19 pandemic, highlighting the need to adapt innovation and collaboration processes to address global challenges. The overall objective of the research was to develop a technology transfer model among public universities in Ibero-America, particularly focusing on Brazil, Costa Rica, Mexico, and Spain, using digital information and communication technologies (ICTs). The exploratory and descriptive research addressed three distinct phases: literature review, application of a qualitative questionnaire, and discussions in focus groups. The results revealed that, despite advanced digital infrastructure and government incentives, there are barriers such as conservative organizational culture and lack of financial resources. The proposed model consists of three macro-phases: pre-transfer, transfer development, and post-transfer - totaling eight phases and fifty-eight operational activities. The importance of assessing digital skills, digital transformation, and intellectual property management to facilitate effective technology transfer is emphasized. This model aims to promote collaboration among universities, stimulating innovation and economic and social development in the Ibero-American region, while highlighting the continuous need for adaptation and improvement of technology transfer processes.

Keywords: technology transfer; technology transfer model; digital transformation; public universities; Ibero-America.

*Resumen. La transferencia de tecnología a través de tecnologías digitales ha surgido como un tema fundamental durante la pandemia de COVID-19, evidenciando la necesidad de adaptar los procesos de innovación y colaboración para enfrentar desafíos globales. El objetivo general de la investigación consistió en desarrollar un modelo de transferencia de tecnología entre universidades públicas de Iberoamérica, especialmente para Brasil, Costa Rica, México y España, utilizando tecnologías digitales de información y comunicación (TDIC). La investigación exploratoria y descriptiva abordó tres fases distintas: revisión de la literatura, aplicación de cuestionario cualitativo y discusiones en grupo focal. Los resultados revelaron que, aunque hay infraestructura digital avanzada e incentivos gubernamentales, existen barreras como la cultura organizacional conservadora y la falta de recursos financieros. El modelo propuesto consta de tres macrofases: pre-transferencia, desarrollo de la transferencia y post-transferencia, con un total de ocho fases y cincuenta y ocho actividades operativas. Se destaca la importancia de la evaluación de competencias digitales, transformación digital y gestión de la propiedad intelectual para facilitar la transferencia efectiva de tecnología. Este modelo tiene como objetivo promover la colaboración entre universidades, estimulando la innovación y el desarrollo económico y social en la región iberoamericana, al tiempo que resalta la necesidad continua de adaptación y mejora de los procesos de transferencia de tecnología.*

*Palabras clave: transferencia de tecnología; modelo de transferencia de tecnología; transformación digital; universidades públicas, Iberoamérica.*

*Resumo. A transferência de tecnologia por meio de tecnologias digitais emergiu como um tema fundamental durante a pandemia da COVID-19, evidenciando a necessidade de adaptar os processos de inovação e colaboração para enfrentar desafios globais. O objetivo geral da pesquisa consistiu em desenvolver um modelo de transferência de tecnologia entre universidades públicas da Iberoamérica, em especial para o Brasil, Costa Rica, México e Espanha, utilizando tecnologias digitais da informação e comunicação (TDICs). A pesquisa exploratória e descritiva abordou três fases distintas: revisão da literatura, aplicação de questionário qualitativo e discussões em grupo focal. Os resultados revelaram que, embora haja infraestrutura digital avançada e incentivos governamentais, existem barreiras como cultura organizacional conservadora e falta de recursos financeiros. O modelo proposto consiste em três macro-fases: pré-transferência, desenvolvimento da transferência e pós-transferência - com um total de oito fases e cinquenta e oito atividades operacionais. Destaca-se a importância da avaliação de*

*competências digitais, transformação digital e gestão da propriedade intelectual para facilitar a transferência eficaz de tecnologia. Este modelo visa promover a colaboração entre universidades, estimulando a inovação e o desenvolvimento econômico e social na região da Iberoamérica, enquanto destaca a necessidade contínua de adaptação e aprimoramento dos processos de transferência de tecnologia.*
*Palavras-chaves: transferência de tecnologia; modelo de transferência de tecnologia; transformação digital; universidades públicas; Iberoamérica.*

## 1. Introduction

Issues regarding technology transfer have been widely discussed by a large portion of researchers and public managers, as it brings benefits to both industry and universities. The process of knowledge production and its implementation by the organizations that produce them constitute themes focusing on innovations (Freeman, 1991; Sutz, 2000; Edler, Krahmer, & Reger, 2002). Few works focus on technology transfer in digital media, a subject directly related to survival on the planet between 2020 and 2022.

During the COVID-19 pandemic, for safety and survival reasons, people had to stay secluded in their homes or establish in-person contact with many safety protocols, and digital technologies were the safest means to continue social contact and work. The production of the vaccine for the development of the first vaccine against the SARS-CoV-2 virus was an important milestone in the fight against the pandemic. Several universities and laboratories around the world worked tirelessly to develop the vaccine in record time, made possible by establishing effective digital technology transfer mechanisms. This was done by the University of Oxford, in partnership with the pharmaceutical company AstraZeneca in the UK, as well as Pfizer in the US, in partnership with the biotechnology company BioNTech in Germany, pioneers in research and results.

Universities and laboratories used a variety of digital mechanisms, including computational modeling, which helped understand how the coronavirus interacts with human cells and how the immune response can be stimulated. The use of artificial intelligence aided in the analysis of data on a large scale. Additionally, the sending of this researched data and the establishment of remote work and communication between laboratories in different parts of the world were facilitated by digital mechanisms. Digital mechanisms were also used for the registration of volunteers for mass clinical trials, to ensure that the vaccine was safe and effective in a wide range of people, accelerating the vaccine development process.

Technology transfer through information and communication digital technologies (ICTs) was fundamental to keeping the economy, education, health, and other sectors functioning during the pandemic. Additionally, it played a important role in disseminating accurate and reliable information about COVID-19, allowing people to take appropriate prevention and protection measures.

Technology transfer (TT) is a mechanism through which universities and the productive sector can achieve and maintain their competitiveness in the market, not only as a result of technological advancement, but also as a result of an attitude of change and adaptation to the human, economic, and social needs of the current world. (Evans & Wurster, 1997; Hsu & Sabherwal, 2011; Gold, Malhotra, & Segars, 2001). The interaction between universities from different nations facilitates the expansion

of technology in various areas of knowledge, enabling the growth of organizations and, consequently, producing greater international, national, or regional economic development. (Hsu & Sabherwal, 2011; Gold, Malhotra, & Segars, 2001, Silva 2024).

Analyzing this interaction and proposing a TT model established through ICTs in public universities in Ibero-America, understanding the advantages and limitations of this process, is an important step for the social, educational, technological, and economic development of society itself since public universities play an important role in this context. This research proposes discussions, and reflections on technology transfer in the context of digital transformation within Ibero-American public universities, which in many approaches do not take into account the specificity of each organization, the region where they operate, and the intrinsic relationship with innovation and intellectual property processes. This study aimed to develop an Ibero-American model of technology transfer among public universities in Brazil, Costa Rica, Mexico, and Spain through digital information and communication technologies.

The pandemic highlighted the importance of ICTs to foster TT as a important tool for addressing global crises and the need for broader and fairer technology transfer to ensure that everyone can benefit from it, but universities need to continue this process, understand the best mechanisms, and propose models that can be effective in this relationship and increasingly foster this activity and drive innovation in their institutions.

## 2. Technology transfer

Technology transfer involves the dissemination or retention of technologies, relevant knowledge, and the results of their implementation. It results in the creation of products or other elements for various stakeholders, including industries, individuals, institutions, or entities (da Silva et al., 2018; Siegel et al., 2023). Essentially, it diffuses technologies from their source to other people and places, driven by the goals of the parties involved. Both the transferred technologies and the transfer process can vary (Winebrake, 1992; Autio & Laamanen, 1995; Ismail et al., 2018; Gerli, Chiodo, & Bengo, 2020; Santos Silva, Ten Caten, & Gaia, 2023).

In this process, technology encompasses not only tangible goods, such as products or hardware, but also intangible assets, such as ideas, knowledge, experience, or software. Some scholars view technology as a combination of tangible and intangible aspects, including physical items, information, hardware, software, products, processes, and know-how (Grosse, 1996; Bozeman, 2000; Buratti & Penco, 2001; Maskus, 2003; Gopalakrishnan & Santoro, 2004; Li-Hua, 2006; Abdul Wahab et al., 2012; Günsel, 2015).

The flow of technology transfer also encompasses various perspectives. A model proposed by Silva, Ten Caten, & Gaia (2023) offers nine categories of transfer flow between universities and the productive sector, such as anthropotechnological evaluation, evaluation of the technology transfer structure, entrepreneurial education, intellectual property, evaluation, technology transfer management, market, society, and environment.

The technology transfer process can be facilitated by mechanisms such as spin-offs, business incubators, licensing, academic publications, meetings, and research and development cooperation agreements (Rogers et al., 2001; Beltran, 2020).

In the context of digital transformation, the financial support provided to improve the digital education of organizations also serves as an important mechanism to promote technology transfer (Ebert & Duarte, 2018; Pisár et al., 2022).

By effectively integrating digital technologies into their transfer processes, universities can accelerate innovation, promote strategic collaborations, and expand the impact of their research activities. Universities need to adopt a proactive approach to harness the full potential of digital transformation and drive technological progress toward a more innovative and sustainable future.

While digital transformation offers advantages in university technology transfer processes, it also presents significant challenges. Issues related to data security, intellectual property, and digital inclusion need to be addressed to ensure that all stakeholders can equally benefit from digital transformation. However, the potential benefits outweigh the challenges, and universities that fully embrace digital transformation are well-positioned to drive innovation and promote technological progress.

### *2.1 Public Policies for science, technology, and innovation in the Ibero-American context*

Public policies for science, technology, and innovation are important instruments for driving scientific and technological progress, promoting competitiveness and economic and social sustainability, and enhancing the quality of life for populations (Thielmann & La Rovere, 2016). In Ibero-America, several countries have implemented various strategies to strengthen their innovation and research ecosystems. This topic will address four representative countries in this study: Brazil, Costa Rica, Mexico, and Spain.

In 1949, the OEI (Organization of Ibero-American States for Education, Science, and Culture) was created as an important organization aiming to foster cooperation among Ibero-American countries in the fields of education, science, technology, and culture (Callou, 2023). The Member States include all Ibero-American countries forming a community of nations integrated by Argentina, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Chile, Dominican Republic, Ecuador, El Salvador, Spain, Guatemala, Equatorial Guinea, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Portugal, Puerto Rico, Uruguay, and Venezuela.

Another significant program is Cyted (Ibero-American Program of Science and Technology for Development), a cooperation program among universities, research centers, companies, and governments in Ibero-America, aimed at promoting research and scientific-technological development in the region (de Saberes, Locales & Vignale, 2010). This program is important for technology transfer from universities in Brazil, Costa Rica, Spain, and Mexico as it fosters scientific and technological collaboration among different countries.

Technology transfer is a important process for the economic and social development of countries as it enables the application of scientific and technological knowledge in solving specific problems and creating new products and services. In this sense, the Cyted program promotes technology transfer among universities through scientific and technological collaboration among different countries.

Under the Cyted program, many research and technology transfer projects have been developed among Ibero-American universities in different areas such as biotechnology, energy, agriculture, health, and education, among others. These projects have allowed the creation of new knowledge and technologies as well as the training of highly qualified human resources in the region (de Saberes, Locales & Vignale, 2010).

Brazil has a long history of investment in science, technology, and innovation, with notable funding agencies such as the National Council for Scientific and Technological Development (CNPq), Coordination for the Improvement of Higher Education Personnel (CAPES), Financier of Studies and Projects (Finep), among others. The country seeks to strengthen its scientific and technological capacities, promote public-private partnerships, and stimulate innovation in strategic sectors such as energy, health, and agriculture.

In 2005, the Good Law (Law 11,196/2005) was created to incentivize companies to invest in research, development, and technological innovation, granting tax incentives. In 2004, the Innovation Law (Law 10,973/2004) was created, an important milestone for Brazil aimed at stimulating innovation in companies through support for research, development, and diffusion of new technologies. In 2016, the Legal Framework for Innovation (Law 13,243/2016) was created with the main objective of promoting and encouraging technological innovation in the country. This framework represents an important step towards consolidating a more conducive environment for research, development, and innovation, aiming to boost competitiveness and socio-economic development.

In 2007, the National Program to Support Technological Innovation in Companies (PRONIT) was created to strengthen technological innovation in Brazilian companies by offering financial and technical support. Despite significant progress, Brazil faces significant challenges, including the need to increase investments in research and development and improve technology transfer to the productive sector.

Costa Rica has emerged in the region as a hub for innovation and entrepreneurship, driven by policies that encourage the development of technological clusters and the attraction of foreign investments. The country invests in quality education and technological infrastructure, seeking to position itself as a technology hub in Central America.

In 1990, the Promotion of Scientific and Technological Development Law (Law No. 7169) and the creation of MICYT (Ministry of Science and Technology) were established to facilitate scientific and technological research and innovation leading to greater economic and social progress within a sustainable development and productivity strategy. In 2008, the Research and Development Support Program (PROINNOVA) was created to promote innovation and technological development in Costa Rican companies. In 2013, the Promotion and Development of Science and Technology Law was created to promote the country's scientific and technological development by providing incentives and financial support.

In 2021, Law No. 9971 was also created, establishing the Costa Rican Innovation and Research Promoter, transforming the National Council for Scientific and Technological Research (Conicit) into the Costa Rican Innovation and Research Promoter,

which constitutes an autonomous institution with legal personality and its assets. The Promoter will be governed by this law, and its regulations, as well as the provisions of Law No. 7,169, Promotion of Scientific and Technological Development, of 1990. The Promoter will be part of the National System of Science, Technology, and Innovation. Despite important advances, Costa Rica still faces challenges related to the training of specialized human resources and the diversification of its productive base.

Mexico has one of the most dynamic economies in Ibero-America, driven by sectors such as manufacturing, information technology, and biotechnology. The country has implemented policies to strengthen its innovation capabilities, such as the National Program for Science, Technology, and Innovation, aimed at strengthening the National System of Science, Technology, and Innovation through the training of human talent and support for research and technological development projects.

In 2002, the Science and Technology Law was created, establishing the foundations for scientific, technological, and innovation development in Mexico, and promoting technology transfer. Another important program created was the Software Industry Development Program (PROSOFT) in 2004, aimed at promoting the development of the Mexican software industry by encouraging innovation and technology adoption. Additionally, Mexico has sought to promote collaboration among universities, research centers, and companies to stimulate technology transfer and the creation of qualified jobs.

Spain has consistently invested in research and innovation, seeking to boost economic growth and international competitiveness. The country has a solid network of research institutions and prestigious universities, as well as fiscal and financial incentives for innovative companies.

In 2007, the National Program for Fundamental Research Projects was created to support basic and applied research in various sectors, aiming to promote innovation and technological development. In 2011, the Science, Technology, and Innovation Law (Law No. 14/2011) was created to promote innovation in Spanish companies by offering tax incentives and financial support. Spain has also focused on emerging areas such as artificial intelligence, renewable energy, and biotechnology to boost its economy and tackle global challenges.

Public policies for science, technology, and innovation play a fundamental role in the sustainable development and competitiveness of Ibero-American countries. Brazil, Costa Rica, Mexico, and Spain have adopted various strategies to promote innovation and technological progress, facing specific challenges in their national contexts. Cooperation and the exchange of best practices among these countries can contribute to strengthening innovation ecosystems and advancing socioeconomic development in the region as a whole.A transferência de tecnologia envolve a disseminação ou retenção de tecnologias, conhecimentos relevantes e os resultados da sua implementação. Resulta na criação de produtos ou outros elementos para diversos stakeholders, incluindo indústrias, indivíduos, instituições ou entidades (da Silva et al., 2018, Siegel et. al., 2023). Essencialmente, difundir tecnologias desde a sua fonte original para outras pessoas e lugares, impulsionado pelos objetivos das partes envolvidas. Tanto as tecnologias transferidas como o processo de transferência podem variar (Winebrake, 1992; Autio e Laamanen, 1995; Ismail et al.,2018; Gerli, Chiodo, e Bengo, 2020, Santos Silva, Ten Caten e Gaia, 2023).

## 3. Methodology

The research, by its nature, constitutes applied research. In terms of objectives, it is descriptive and exploratory. The approach was qualitative. This study focused on public universities in Ibero-America, such as Brazil, Costa Rica, Mexico, and Spain, and occurred in three distinct phases, as shown in Figure 1 below

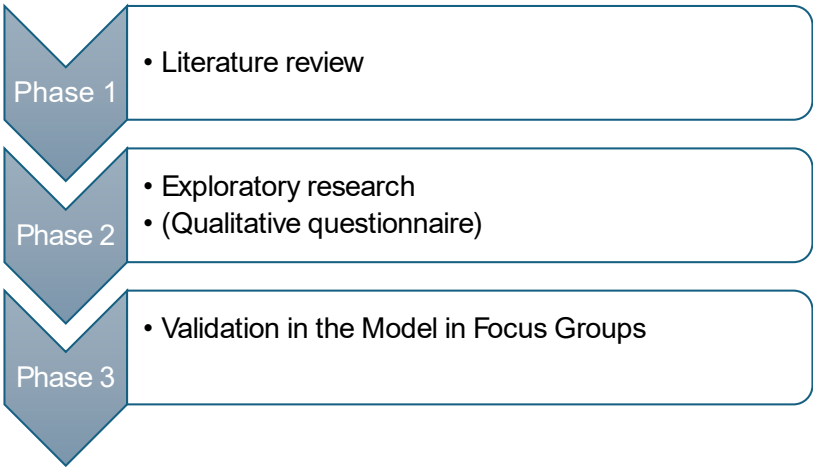


Figure 1. Stages of the methodology applied
Source: own elaboration.

The first phase consisted of surveying the international literature for conceptual models of technology transfer. This phase aimed to understand existing models and analyze their correlation with the use of digital information and communication technologies.

The second phase involved the application of a qualitative questionnaire with the following open-ended questions:

1. What are the main supportive factors for the technology transfer process among universities in Ibero-America using digital information and communication technologies?
2. What barriers are encountered in the technology transfer process among universities in Ibero-America using digital information and communication technologies?
3. What activities are necessary to initiate or improve cooperation among universities in Ibero-America using digital information and communication technologies?

The questionnaire was sent to 841 researchers and professors from research groups at 5 public universities of reference in Ibero-America, representing countries corresponding to different geographical regions of Ibero-America: two in South America (Brazil), one in Central America (Costa Rica), one in North America (Mexico), and one in Europe (Spain). The questionnaire response rate was 64%, resulting in 542 completed questionnaires across the four countries, collected from April to October 2023. The questionnaire was administered electronically using the Google Forms tool.

The aim of applying the qualitative questionnaire to research groups in public institutions was to understand stimulus factors, and barriers in the technology transfer process, and to comprehend the best way to develop a conceptual model to stimulate this process.

The third phase involved the development of the conceptual model and its validation with focus groups.

The focus group discussion method was employed to engage experts and active researchers in the field of technology management and innovation. According to Gomes & Barbosa (1999), this approach provides an opportunity for introspection, validation, and reassessment of the proposed model, as well as promoting critical reflection on daily research practices.

The focus group was conducted to establish a dialogue with professors and researchers from different research groups/laboratories, enriching contexts not specified by other data collection techniques, while allowing observation of interaction among participants. The focus group sessions were scheduled in advance to facilitate participant involvement, with 11 sessions held between November and December 2023, each lasting approximately 1 hour. During the sessions, the conceptual model created was presented for feedback from the interviewees.

## 4. Results and discussions

Through research conducted at public universities in Ibero-America with their respective research groups, it was possible to identify the main barriers, stimulus factors, and activities that should be developed to initiate and improve the technology transfer process using digital mechanisms.

It was observed that technology transfer through digital mechanisms is not yet widely understood among the investigated research groups.

Table 1 presents the top 5 incidences in questionnaire responses regarding the main answers concerning cooperation among universities.

Table 1 - Observed barriers and supportive/stimulus factors

| Support and Stimulus Factors | Barriers | Atividades para Iniciar ou Melhorar a Cooperação |
|---|---|---|
| • Advanced Digital Infrastructure.<br>• Collaboration Networks.<br>• Government Policies and Incentives.<br>• Innovation Culture.<br>• Intellectual Property Training | • Conservative Organizational Culture.<br>• Legal and Regulatory Barriers.<br>• Lack of Financial Resources.<br>• Linguistic and Cultural Barriers.<br>• Lack of Market Connection. | • Establishment of Collaborative Digital Platforms.<br>• Technology Transfer Training Programs.<br>• Financial Incentives.<br>• Development of Collaboration Networks.<br>• Exchange of Experiences and Best Practices. |

Source: Author's contribution.

Through the research, it was observed that concerning stimulus factors, the most prominent ones are:

- IAdvanced Digital Infrastructure: The surveyed universities possess advanced digital infrastructure, granting them a significant advantage in technology transfer. This enables more efficient communication and remote collaboration among researchers using digital mechanisms such as Skype, Zoom, Google Hangouts/Meet, Microsoft, Discord, and Meetfox, among others.
- Collaboration Networks: There is an ongoing formation of collaboration networks among universities and research institutions to facilitate knowledge and resource sharing, aiming to ease technology transfer.
- Government Policies and Incentives: Government policies in the four researched countries (Brazil, Costa Rica, Mexico, and Spain) incentivize technology transfer and provide financial support for collaborative research projects, which can stimulate cooperation among universities.

For instance:

- In Brazil, the Innovation Law (Law No. 10,973/2004) establishes measures to encourage innovation and scientific and technological research in a productive environment. It promotes cooperation between universities, research institutes, and companies for collaborative project development. Additionally, research funding agencies such as the Financier of Studies and Projects (FINEP) and the National Council for Scientific and Technological Development (CNPq) offer financing for collaborative research projects.
- In Costa Rica, the Research and Technological Innovation Financing System (SIFCIT), managed by the Ministry of Science, Technology, and Telecommunications (MICITT), provides financial support for research and technological development projects. SIFCIT can finance collaborative projects between universities, research institutes, and companies aiming at technology transfer and innovation.
- In Mexico, the Program for the Development of the Software Industry (PROSOFT), coordinated by the Ministry of Economy, aims to promote the competitiveness and innovation of the Mexican software industry. It offers financial incentives such as grants and financing for collaborative research and development projects between universities, companies, and research centers.
- In Spain, the National Plan for Scientific Research, Technological Development, and Innovation is the main instrument of Spain's scientific and technological policy. The plan includes various measures to support research and innovation, such as funding for collaborative projects between universities and companies, as well as promoting technology transfer through incentives and specific programs.

Innovation Culture: The surveyed universities foster a culture of innovation and entrepreneurship through regional innovation offices, business incubators, and technology parks, which are more likely to actively engage in technology transfer, seeking to apply their knowledge to practical solutions.

Intellectual Property Training: Universities seek to train researchers and university managers in intellectual property issues, understanding it as fundamental to protect and commercialize research results, thus encouraging technology transfer.

Regarding barriers to technology transfer, the most evident factors are:

Conservative Organizational Culture: Respondents highlighted that some universities may have a conservative organizational culture, hindering the adoption of new technology transfer practices and digital collaboration.

Legal and Regulatory Barriers: Legal issues such as complexities in intellectual property, technology import/export, and regulations on technology transfer may create obstacles to cooperation among Ibero-American universities.

Lack of Financial Resources: Inadequate funding for networked research and development can limit universities' capacity to invest in digital technologies and technology transfer initiatives.

Linguistic and Cultural Barriers: Linguistic and cultural differences among Ibero-American countries may hinder communication and effective collaboration among researchers and institutions, as countries within this axis speak languages such as Portuguese and Spanish.

Lack of Market Connection: Universities may struggle to identify market opportunities and establish partnerships with companies interested in commercializing developed technologies.

Regarding activities to initiate or improve cooperation, the most evident factors are:

Establishment of Collaborative Digital Platforms: Respondents emphasized the need to develop and promote the use of collaborative digital platforms that facilitate communication and resource sharing among universities.

Technology Transfer Training Programs: It was identified that universities should implement technology transfer training programs for researchers and university managers, addressing issues such as intellectual property, commercialization, and contract negotiation.

Financial Incentives: Respondents listed that creating specific financial incentives can promote collaboration among universities in Ibero-America, including funding for collaborative research projects and support for technology commercialization.

Development of Collaboration Networks: It was identified that universities should foster the development of collaboration networks among universities and research institutions, promoting knowledge and resource sharing.

Exchange of Experiences and Best Practices: It was also identified that exchanging experiences and best practices among Ibero-American universities that have been successful in technology transfer can encourage mutual learning and the adoption of effective strategies.

The research conducted among public universities in Ibero-America revealed important insights into the barriers, stimulating factors, and necessary activities for promoting technology transfer using digital mechanisms. Although technology transfer

through such mechanisms is not yet widely understood or applied by the research groups investigated, the collected data provides a solid foundation for analyzing the challenges and opportunities in this field.

Initially, the observed stimulating factors highlight the importance of advanced digital infrastructure in the surveyed universities, which serves as an effective enabler for technology transfer. This infrastructure allows for more efficient communication and remote collaboration among researchers, using digital platforms such as Skype, Zoom, and Google Meet. In the context of the research, this finding suggests that universities with significant investments in information technology are better positioned to advance technology transfer processes, benefiting from a smoother integration between different stakeholders.

Another important factor identified is the existence of collaboration networks between universities and research institutions. This finding indicates that the formation of partnerships and networks is a central component for success in technology transfer, as it facilitates the sharing of knowledge and resources. In the context of the research, these collaboration networks can be seen as the backbone of regional innovation, promoting a synergy that transcends the individual limitations of institutions.

Government policies and incentives also emerged as a determining factor. The research identified that the countries involved, such as Brazil, Costa Rica, Mexico, and Spain, have specific legislation and programs that encourage cooperation and technology transfer. This finding underscores the importance of government support as a catalyst for innovation. In the broader context, such policies not only foster interinstitutional collaboration but can also reduce structural barriers that hinder technology transfer.

A culture of innovation and capacity-building in intellectual property were identified as factors that positively influence technology transfer. The promotion of a culture of innovation through incubators and technology parks suggests that universities that encourage entrepreneurship are more inclined to apply their knowledge to practical solutions. Similarly, capacity-building in intellectual property is relevant for protecting and commercializing research results, highlighting the need for specialized knowledge to navigate the legal and market complexities involved.

On the other hand, identified barriers such as a conservative organizational culture, legal and regulatory barriers, lack of financial resources, linguistic and cultural barriers, and lack of market connection point to structural and contextual challenges that need to be addressed for technology transfer to become more effective. For example, a conservative organizational culture can be a significant obstacle, limiting openness to new practices and digital innovations. In the context of the research, these challenges indicate priority areas for intervention and institutional reform, suggesting that cultural transformation can be as important as technological advances.

The activities proposed to initiate or improve cooperation between universities, such as the establishment of collaborative digital platforms and capacity-building programs in technology transfer, point to concrete actions that can be implemented to overcome barriers and maximize stimulating factors. In the context of the research,

these activities represent strategic steps that, if adopted, could transform the current landscape, creating a more conducive ecosystem for innovation and technology transfer in Ibero-America.

The research findings not only identify the key factors influencing technology transfer but also offer a clear vision of the necessary interventions to promote interinstitutional cooperation and overcome existing challenges. The discussion of the findings reveals the importance of an integrated approach that combines investment in infrastructure, strengthening of collaboration networks, government support, and the development of a culture of innovation, so that Ibero-American universities can fully capitalize on the opportunities provided by digital mechanisms for technology transfer.

### *4.1 Technology transfer model proposal*

The conceptual model of technology transfer has been divided into three macro-phases, eight phases, five Gates 2, and fifty-eight operational activities for the application of the model in universities of Ibero-America. In Figure 2, the framework of the conceptual model can be observed:

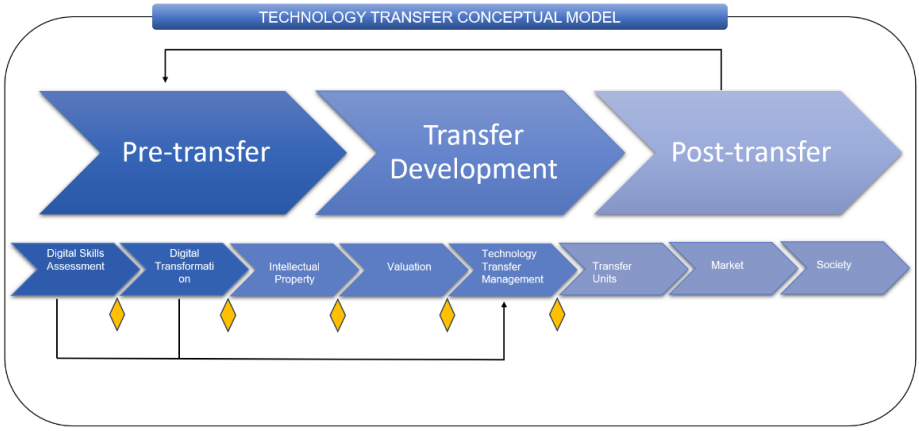


Figure 2. Ibero-American technology transfer conceptual model
Source: Author's contribution

The model developed in the research was based on the model elaborated by Silva, Ten Caten & Gaia (2023), the green technology transfer model for Brazilian public universities, in this model there is division by macro-phases in pre-transfer, transfer development, and post-transfer.

In the first macro-phase "pre-transfer," there are two phases, two Gates, and fourteen activities, as follows: Figure 3: A proposed conceptual model of technology transfer. The first phase consists of "assessment of digital skills," the objective of the phase is to assess the internal digital skills of the university to establish technology transfer with other units.

At this stage, the activities of the phase comprise (i) Planning assessment strategy, (ii) Define team, (iii) Define activities and sequence, (iv) Develop schedule, (v) Define tools for assessment of digital skills, (vi) Define performance indicators, Gate 1 - Evaluate assessment strategies, and (vii) Develop final report.

The second phase consists of "digital transformation," the objective of the phase is to assess and diagnose how the university incorporates the use of digital technology into its management structure to foster technology transfer with other units.

In many cases, people involved in the technology transfer process do not make a prior diagnosis of the adoption of technology in the units involved. Many problems can be avoided beforehand if a diagnosis is made and subsequently, an action plan is developed to partially or eliminate the gaps found.

At this stage, the activities of the model comprise: (i) Planning pedagogical strategies for digital transformation, (ii) Develop digital transformation through the use of information and communication technologies, (iii) Develop workshops and practical training, (iv) Integrate TTOs with research groups, undergraduate, and graduate courses. Gate 2 - Evaluate digital transformation strategy. (v) Foster the creation of internal and external communication networks, (vi) Develop final report.

In the second macro-phase "transfer development," there are three phases, three Gates, and twenty-four activities, as follows:

The first phase consists of "intellectual property management," the objective is to develop the intellectual property plan for the university. This stage is predominant in more traditional models, as it addresses the comprehensive management of intellectual creations subject to protection and patenting. The suggested model emphasizes this phase and incorporates it into the others developed.

At this stage, the activities of the model comprise: (i) Identifying technologies aimed at international cooperation, (ii) Prospecting technological priority, (iii) Evaluate technology, (iv) Seek investors for the invention, (v) Gate 4 - Evaluate management strategies, and (vi) Protection (drafting, filing, and monitoring).

The second phase consists of "valuation," the objective is to develop a technological valuation plan. Technology valuation represents one of the main challenges in the technology transfer process, as there is a shortage of professionals with specific skills to carry out this assessment.

At this stage, the activities of the proposed model comprise: (i) Plan valuation strategy, (ii) Define team, (iii) Define activities and sequence, (iv) Develop a schedule, (v) Define tools for technology valuation, (vi) Analyze opportunities and risks of technology, (vii) Analyze commercial potential, (viii) Analyze technical aspects of technology, (ix) Gate 5 - Evaluate valuation plan, and (x) Analyze technology value.

The third phase consists of "technology transfer management," the objective of the phase is to develop the technological management planning of the university.

At this stage, there is full integration between internal innovation centers for the implementation of transfer in the international environment. Technology managers must be attentive to the dynamics that occur in other universities in Ibero-America to be flexible and ensure that everything goes as planned.

At this stage, the activities of the model comprise: (i) Define the integration plan of the sector, research groups/laboratories, and incubator with the productive sector, (ii) Define technology dissemination strategy, (iii) Define technology transfer strategy, (iv) Define technology transfer mechanisms, (v) Prospect potential international clients in Ibero-America (companies and entrepreneurs), (vi) Develop negotiation plan, (vii) Gate 6 - Evaluate management plan, and (viii) Record technology contract.

In the third macro-phase "post-transfer," there are three phases and twenty activities, as follows:

The first phase of this stage constitutes the "transfer units," the objective is to diagnose the impacts of information and communication technologies used between transfer units. The idea is to monitor and assess the impacts of the use of technology on cooperation between universities.

At this stage, the activities of the model comprise: (i) Define tools for evaluating the impacts of the use of information and communication technologies in transfer units, (ii) Assess impacts on the updating of digital technologies in the technology transfer process, (iii) Propose action and improvement plan, (iv) Develop schedule, (v) Develop final report.

The second phase of this stage constitutes "market," the objective is to monitor and assess the impact on the market of technologies that have been transferred between transfer units. The idea is to monitor and assess the impacts of the use of technology on cooperation between universities.

At this stage, the activities of the model comprise: (i) Plan research strategy, (ii) Define team, (iii) Define activities and sequence, (iv) Develop a schedule, (v) Define a plan to monitor technology participation in the market, (vi) Define tools for market monitoring, (vii) Monitor the participation of similar products (competitors), (viii) Develop final report.

The third and final phase constitutes "society," the objective is to diagnose the social impacts of the technologies that have been transferred.

The success of technology transfer can be compromised if society fails to adjust adequately to the transferred technology. Monitoring the impacts on consumer society can be a viable approach to ensure that this process occurs effectively and with fewer negative consequences. The goal is to understand this reality and seek to reduce such impacts.

At this stage, the activities of the model comprise: (i) Plan research strategy, (ii) Define team, (iii) Define activities and sequence, (iv) Develop schedule, (v) Define tools for evaluation, (vi) Evaluate social impacts of transferred technology, (vii) Develop final report.

The detailed macro-phases, phases, objectives, and activities of the proposed TTV model can be observed in Table 2.

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Table 2. Detailing of the technology transfer model

| Macro-phase | Phase | Phase objective | Activities |
|---|---|---|---|
| Pre-transfer | Evaluation of Digital Skills | Evaluate and diagnose internal digital competencies for the technology transfer process | Strategy planning for assessment |
| | | | Team definition |
| | | | Schedule development |
| | | | Activity and sequence definition |
| | | | Schedule development |
| | | | Definition of Questionnaire for Digital Competence Assessment |
| | | | Definition of performance indicators |
| | | | Gate 1 - Evaluate assessment strategies |
| | | | Final report elaboration |
| | Digital Transformation | Promote digital transformation with the use of information and communication technologies | Pedagogical strategies planning for digital transformation |
| | | | Development of digital transformation through the use of information and communication technologies |
| | | | Development of workshops and practical training |
| | | | Integration of TTOs with research groups, undergraduate, and graduate courses |
| | | | Gate 2 - Evaluate digital transformation strategy |
| | | | Promotion of internal and external communication network creation |
| Development of the transfer | Intellectual property | Desenvolver o plano de propriedade intelectual junto a universidade | Identification of technologies aimed at international cooperation |
| | | | Prospecting of technological prior art |
| | | | Technology assessment |
| | | | Investor search |
| | | | Gate 3 - Evaluate management strategies |
| | | | Protection (drafting, filing, and monitoring) |
| | Valuation | Develop the intellectual property plan with the university | Valuation strategy planning |
| | | | Team definition |
| | | | Activity and sequence definition |
| | | | Schedule development |
| | | | Definition of valuation tools |
| | | | Opportunities and risks analysis of the technology |
| | | | Commercial potential analysis |
| | | | Technical aspects analysis of the technology |
| | | | Gate 4 - Evaluate valuation plan |
| | | | Technology value analysis |

| | | | |
|---|---|---|---|
| Development of the transfer | Technology transfer management | Develop a technological valuation plan | Definition of the sector integration plan, research groups, and incubator with the productive sector |
| | | | Technology dissemination strategy definition |
| | | | Technology transfer strategy definition |
| | | | Technology transfer mechanisms definition |
| | | | Prospecting of potential international clients in Ibero-America (companies and entrepreneurs) |
| | | | Negotiation plan elaboration |
| | | | Gate 5 - Evaluate management plan |
| | | | Technology contract registration |
| Post-transfer | Units of transfer | Diagnose the impacts of information and communication technologies used between transfer units | Research strategy planning |
| | | | Team definition |
| | | | Activity and sequence definition |
| | | | Schedule development |
| | | | Definition of tools for assessing the impacts of the use of information and communication technologies on transfer units |
| | | | Evaluation of impacts on the updating of digital technologies in the technology transfer process |
| | | | Action and improvement plan proposal |
| | | | Final report elaboration |
| | Market | Monitor the market scenario for technologies that have been transferred | Research strategy planning |
| | | | Team definition |
| | | | Activity and sequence definition |
| | | | Schedule development |
| | | | Definition of technology market participation monitoring plan plano de acompanhamento da participação da tecnologia no mercado |
| | | | Definition of tools for market monitoring |
| | | | Monitoring of similar products (competitors) participation |
| | | | Final report elaboration |
| | Society | Diagnose the social and digital impacts of technologies that have been transferred | Research strategy planning |
| | | | Team definition |
| | | | Activity and sequence definition |
| | | | Schedule development |
| | | | Definition of tools for social and digital impacts assessment |
| | | | Evaluation of social and digital impacts of transferred technology |
| | | | Final report elaboration |

Fonte: Author's contribution

The information generated in the reports of the last three post-transfer phases can serve as support and guidance in the first two macro-phases. The phases of the proposed conceptual model can be applied independently, which should take into consideration the reality of the university and the needs of the market.

## 5. Conclusions

The research on technology transfer through digital information and communication technologies (ICTs) among public universities in Ibero-America has achieved its objective and revealed significant advances, identified relevant barriers, and opened up new perspectives for the economic and social development of the region, proposing a conceptual model to improve these activities at the international level.

The progress achieved during the study highlights the growing importance of technology transfer as an important tool to address global challenges, such as the COVID-19 pandemic. It was observed that ICTs played a fundamental role in maintaining the continuity of economic, educational, and health activities during this challenging period. Additionally, the rapid production and distribution of vaccines against the SARS--CoV-2 virus highlighted the effectiveness of digital technology transfer mechanisms in accelerating the development and implementation of innovative solutions.

However, the research also identified several barriers that may hinder the effectiveness of technology transfer among universities in Ibero-America. Among these barriers, the conservative organizational culture, lack of financial resources, legal and regulatory barriers, and linguistic and cultural difficulties stand out. These obstacles emphasize the need for flexible and adaptable approaches that take into account the specificities of each context and promote more effective collaboration between institutions.

Faced with these challenges, the proposed technology transfer model offers a solid framework to facilitate cooperation among universities in Ibero-America, especially Brazil, Costa Rica, Spain, and Mexico. With three macro-phases and their respective operational activities, the model seeks to overcome the identified barriers and promote more effective knowledge and innovation transfer. The importance of continuous evaluation of digital skills, digital transformation, and intellectual property management to ensure the success of this process is highlighted.

As we move towards the future, public universities in Ibero-America need to continue exploring new forms of collaboration and innovation, fully leveraging the potential of ICTs. By promoting broader and fairer technology transfer, these institutions can play a vital role in the economic and social development of the region, contributing to a more prosperous and sustainable future for all.

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