Lecture Notes in Educational Technology

Daniel Burgos
John Willian Branch *Editors*

Radical Solutions for Digital Transformation in Latin American Universities

Artificial Intelligence and Technology 4.0 in Higher Education

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Foreword

Behind the veil of each night, there is a smiling dawn
Kahlil Gibran

Are Higher Education Institutions (HEIs) reluctant to changes? Indeed, we can agree they are. In fact, we can assure HEIs are guardians of tradition, similar to Roman God Janus usually depicted as having two faces, the God of transitions and doorways. One face looks to the past and the other towards the future. University reluctance guarantees some fundamental aspects for knowledge development but at the same time, it generates obstacles for immediate transformations.

One of the most important transformations is the digital one. Not only due to its technological characteristics, but because of the need of cultural and mental changes among those who live the life inside universities, as faculties, students, government managers, administrative staff, etc.

The most vertiginous transformations end, most of the times, in revolutions. The best example was the first Industrial Revolution, which implied fundamental changes in the life of the people in the world and affected the way in how people were in relation to knowledge and the possibilities of life structure changes.

In a lower scale, the realities that we are facing today in HEI, especially the cultural, mental and digital transformations, could turn into a revolution, because it overflows our capability of adaptation to the velocity of change that modern society is expecting.

Latin America and their HEI, despite sharing a lot of cultural aspects, are extremely vast in territory and population. The changes and adaptations needed in the different regions, generates not only expectative but huge challenges facing digital transformation. Because of that, it is necessary to define a roadmap, especially in relation to HEI administration, infrastructure and organization.

Among the challenges that we can emphasize on are: overpopulation, level of dispersion of such population, access to technology, demographic distribution, social and cultural realities and stakeholders interest. Particularly, students are playing a fundamental role. Generational distances nowadays are longer than ever, and the skills the world is looking forward, especially soft ones are essential in a planet plenty of uncertainties.

On the other hand, some aspects in relation to HEI management, such as curriculum adaptations, online grading, alumni relationship, among other, are dimensions with a high potential level to be analysed by the light of digital transformation and 4.0 technologies.

Other challenges HEI must face, from a perspective of opportunities and obstacles, are those related to communicational technologies. Transmission of reliable and timely information to selected and specialized groups, in order to avoid saturation inside the community, must be a priority that is essential from the transformation proposed in this book.

Human dimension and biocentric ethic policies, framed in a global perspective based on sustainability, are central axes of the university management in a world full of challenges and uncertainties generated by the pandemic crisis that we are facing today. Disruptive scenarios in a social perspective can be barriers affecting the satisfaction of needs in academic communities. The organic changes in HEI have been presenting the increasing interest of digital transformation. Those challenges are framed in transformations that must have a holistic glance with the aim of coming through the most important values achieved by humanity.

All these aspects which have been addressed are only an invitation to reflect on the importance that this book is showing us, facing the transformations that must be developed from the technological revolutions inside the Latin American universities.[1]

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[1] The affiliation of author Camilo Younes-Velosa has been corrected in Foreword page.

Preface

University as the epicentre of knowledge, research and innovation, and driving forces of development in Latin America, nowadays face a challenge that demands of itself an internal vision and capacity that allows it to maintain its self-regulation while reaching its own digital transformation. Furthermore, its permanent relationship with the environment allows to measure its relevance and measure to the extent in the adequate and timely response to the requirements of society and industry.

The Fourth Industrial Revolution has led universities in Latin America to rethink themselves, see in perspective their condition and how they are related to a changing environment that projects their development and growth in the Fourth Industrial Revolution. Therefore, presenting to the universities of Latin America a valid study and analysis scenarios that require assimilation to immerse themselves in digital transformation processes where disruptive technologies such as artificial intelligence converge is key.

To this regard, there are three main strands in this book: (1) Higher Education Institutions in Latin America are usually well rooted but not adapted to what the future requires. Processes, management structures, decision procedures and educational methodologies are very much focused on traditional measures, which are usually slow and have proven not too effective. Universities need an upgrade on many levels, and digital transformation seems to be the key. The first three chapters by Zapata Jaramillo, Rodríguez and Zapata Cortés, as main or corresponding authors, address this strand

As a second strand (2), Latin America requires an urgent implementation of an action plan on digital transformation. Every country has a different context, but all of them share the need to update the use of Information and Communication Technologies at various levels. The risk to stay behind a reasonable degree of progress based on a sensible application of technology is too high to hide. The fourth to seventh chapters, by Díez, Simonette, Argüelles and Castillo, work on this strand

The last strand (3) concentrates on artificial intelligence and Technologies 4.0. These are basic tools for change and progress today. Analysis, decisions, tracking and assessment are based on real-time, multi-sourced information dashboards. They require the integration of a number of user groups, including students and professors, but also academic managers, content providers and the wider society. The proper integration of these technologies will allow for an improvement in the service provision and goals achievement in higher education and the correlated knowledge transfer to that society. The eighth to thirteenth chapters, by Castro, Zapata Jaramillo, Yábar, Martínez, Rigaud and Moreno, provide insights to this extent.

This book is a guiding element that facilitates the understanding of how artificial intelligence helps and integrates digital transformation in Higher Education Institutions from education innovation in the following scenarios: learning environments (learning innovation, learning management systems, data and analytics), emerging education trends (business trends, strategic technologies), administrative systems (recruit, retain, advance, enterprise business capabilities, student information system), digital strategy execution (business models and opportunities, strategic planning and governance).

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Contents

Higher Education (HE) Across the Continent. How HE Is Addressed by Region

Edison Spina, Carlos Mario Zapata-Jaramillo, and Marcel Simonette

Abstract Industry 4.0 and digital transformation are hot topics in Latin America related to higher education. Some authors explore such topics from different points of view. However, we need to understand the context surrounding higher education in Latin America to weigh the challenges and opportunities these hot topics face in our region. Accordingly, in this chapter, we propose a knowledge representation of the context of higher education in Latin America based on the so-called pre-conceptual schemas. We aim to provide a framework for understanding how to implement the solutions proposed in the remainder of this book, related to the different fields of Industry 4.0 and digital transformation. We start by performing a state-of-the-art review of the context of higher education in Latin America. Then, we identify the main concepts and relationships addressed in the resulting papers to unify terminology about this context. Finally, we develop the pre-conceptual schema, and we discuss findings based on such knowledge representation. Moreover, the pre-conceptual schema presented in this chapter can be used to identify interconnections and relationships among the diversity of solutions and cases proposed in this book.

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1 Introduction

A new industrial revolution is in place, and higher education institutions have to react in order to adapt themselves to the challenges proposed by the digital transformation linked to such revolution. According to Lambrechts and Sinha (2021), such reaction is difficult to achieve in emerging markets, just like Latin American countries.

Some authors explore this trend from different perspectives sharing the main implications for higher education in Latin American countries (Delprato & Akyeampong, 2019; Fischman & Ott, 2018; Gacel-Ávila, 2018; Guiroy et al., in press; Hilliger et al., in press; Izaguirre & Capua, 2020; Katz & Callorda, 2018; Lemaitre, 2018; Neidhöfer et al., 2018; Sanabria-Pulido et al., 2016; Torres-Samuel et al., 2020; Viloria et al., 2020), but they usually lack a holistic vision, including multiple perspectives. Such holistic vision can be used as a conceptual framework for understanding the main concepts and relationships linked to this trend. Consequently, we propose a graphical way to summarize such perspectives to recognize the main concepts and relationships linked to the digital transformation in Latin American higher education institutions, and we provide a so-called pre-conceptual schema (Zapata et al., 2006) for mapping such elements. Pre-conceptual schemas are knowledge representations closer to the natural language for drawing and understanding the information related to a particular domain. We follow a three-phase method for completing our pre-conceptual schema:

- **State-of-the-art review**. We systematically look for papers/chapters related to digital transformation in higher education in Latin America.
- **Terminology unification**. We collect a corpus with the papers/chapters from the previous stage in order to identify the main concepts and relationships. Then, we determine the equivalences among terms.
- **Pre-conceptual schema development**. We draw the elements identified in the previous phase by using the graphical syntax of the pre-conceptual schemas.

Finally, we analyze the background documents (Delprato & Akyeampong, 2019; Fischman & Ott, 2018; Gacel-Ávila et al., 2018; Guiroy et al., in press; Hilliger et al., in press; Izaguirre & Capua, 2020; Katz & Callorda, 2018; Lemaitre et al., 2018; Neidhöfer et al., 2018; Sanabria-Pulido et al., 2016; Torres-Samuel et al., 2020; Viloria et al., 2020) by using the resulting pre-conceptual schema. We aim this pre-conceptual schema which can be used for reviewing and analyzing the remainder chapters of this book, so the solutions proposed can be clearly understood.

This Chapter is organized as follows: we present a theoretical framework in Sect. 2; then, we discuss some background in Sect. 3; after that, we apply the three-phase method for developing our pre-conceptual schema in Sect. 4 and summarize the results; finally, we discuss conclusions and propose future work in Sect. 5.

2 Theoretical Framework

2.1 Digital Transformation in the Fourth Industrial Revolution

Fetting et al. (2018) link digital transformation to industry 4.0 as a new manner to organize and control the whole value chain by incorporating real-time availability and horizontal/vertical integration. They also categorize four dimensions to succeed in digital transformation:

- **Corporate strategy**. Industries need a change in the corporate strategy for answering challenges arising from new competitors, changes in the market, and technological modifications to the environment. Changes in the vision, the business model, and the conception of autonomy and flexibility are needed.
- **Work organization**. The way of working and the structure of the companies should turn to agile, technological, and competitive organizations.
- **Human Resource development**. Hierarchies should be flattened, and the way to manage human resources should change for promoting creativity, innovation, and autonomy. Education and training are crucial in this scenario.
- **Cultural aspect**. Cultural change leads the transformation toward organizations and nations more productive and prone to answer the challenges of industry 4.0

2.2 Pre-conceptual Schemas

Zapata et al. (2006) define pre-conceptual schemas as knowledge representations closer to the natural language of the stakeholder for obtaining other conceptual schemas used in software development. Knowledge representations can help to the migration from implicit to explicit knowledge, considering that we can identify and collect concepts and relationships from a domain in a graphical easy-to-read structure. Main elements of pre-conceptual schemas (Noreña, 2020) are depicted in Fig. 1. However, we only use the following elements in this chapter:

- **Concepts**. Nouns and noun phrases identified from the stakeholder discourse. Concepts can be class or leaf concepts. In the first case, concepts are heading a structural relationship. In the second case, concepts are linked to structural relationships, but they are no heading them.
- **Structural relationships**. Verbs for generating permanent relationships between concepts, corresponding to is-a (verb to be) and whole-part (verb to have) relationships in a taxonomy
- **Notes-values**. The possible value assigned to a leaf concept.
- **Achievement relationships**. Verbs for expressing improvement/maintenance/realization.

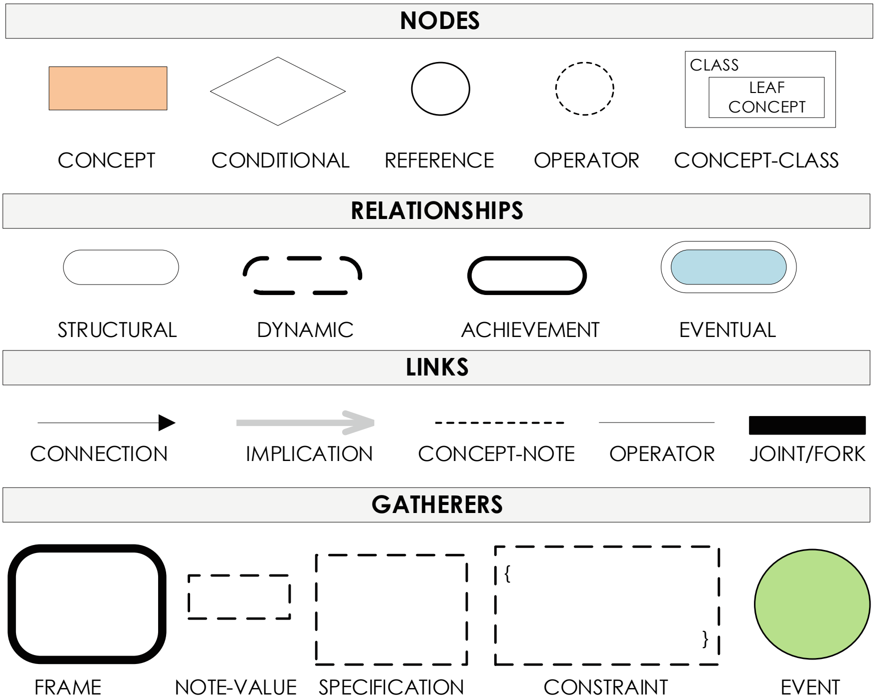

Fig. 1 Main symbols of the pre-conceptual schemas (*Source* Noreña, 2020)

- **Connections**. One-direction arrows for linking concepts to structural relationships and vice versa.
- **Concept-note links**. Dotted lines for connecting concepts to notes-values or achievement relationships to other elements.

3 Background

In this section, we summarize some perspectives related to the features and challenges of higher education in Latin American countries. Delprato and Akyeampong (2019) discuss how Latin American working students are affected in their learning by performing a survey in some countries of the region. They discover working students have some barriers to learning as their work is more related to low payment and low skills. Similarly, Fischman and Ott (2018) discuss other problems affecting Latin American students from public universities, like out-of-date curricula and methods, the politicized influence of groups resistant to change, and bureaucratic administrative systems. Gacel-Ávila et al. (2018) define internationalization in Latin America higher education and presents the main benefits (international recognition of student profiles, quality improvement, and curriculum improvement) and barriers (insufficient financing, lack of linguistic skills, and bureaucratic procedures) that this process faces in the region. Guiroy et al. (in press) explore the access to education and technology, and they find limited resources like cost, scarce technologies, and difficult educational opportunities. Hilliger et al. (in press) identify some needs for adopting analytics learning in Latin American universities like the feedback and timely support for the students, the timely alerts and the meaningful performance evaluations for the teaching staff, and the information to implement support interventions for the managers. Izaguirre and Di Capua (2020) explore the incidence of endogenous peer effects in secondary education in Latin America by applying a social interaction model. Katz and Callorda (2018) develop a comprehensive digitalization index for assessing the econometric development impact of digitalization in Latin America. They discover some advanced countries and other developing countries in the region in terms of supply and penetration of broadband services. Lemaitre et al. (2018) define autonomy and accountability in higher education in Latin America by recalling the history behind some countries of the region; she discovers that governmental policies and market demands often regulate higher education institutions. Neidhöfer et al. (2018) apply some indexes for exploring the causes and consequences of the intergenerational persistence of inequality in education in Latin America. Their findings show a growing trend to intergenerational mobility, "positively associated with economic growth and progressive public expenditure in education, but negatively associated with income inequality, poverty, returns to education, and the degree of assortative mating" (Neidhöfer et al., 2018, p. 345). Sanabria-Pulido et al. (2016) compare public affairs education between Latin American countries with more developed countries. They conclude that the Latin American model is entirely different from the US and the European model. Torres-Samuel et al. (2020) assess some factors related to progress in research and development, science and technology, education, and innovation in Latin American countries. They find that the gross domestic product is the most important factor for contributing to research and development expenses, especially in high technology. Viloria et al. (2020) perform a study about the patterns of use of mobile digital devices in ten Hispanic American institutions. They conclude that tablets and laptops are used in such universities for academic information search, study, and consultation of university services. In contrast, smartphones are used for exchanging academic information, chatting via instant messaging, checking email, and interacting on social networks.

The aforementioned authors study multiple perspectives, but we lack a holistic view of the context of higher education in Latin America. Such a view can be used as a conceptual framework for exploring the solutions proposed throughout this book. For this reason, we propose a pre-conceptual schema at the end of the next section for graphically summarizing the concepts and relationships affecting higher education in Latin America.

4 The Way to Manage Higher Education in Latin America: A Pre-conceptual-Schema-Based Summary

Terminological unification is needed for understanding multiple perspectives related to the same topic. In the previous section, we identify some factors, problems, challenges, benefits, and concepts associated with higher education in Latin America, but we lack a holistic vision of such perspectives. We follow a method based on three phases for solving this problem: a state-of-the-art review, terminology unification, and pre-conceptual schema development, as depicted in Fig. 2. We develop such phases in the following subsections.

4.1 State-of-the-Art Review

The first phase of our method is related to the performance of a state-of-the-art review, and Kitchenham et al. (2009) propose a method for performing systematic literature reviews in software engineering. Such a method can be used in any field of knowledge. We follow this method for identifying papers/chapters related to digital transformation in higher education in Latin America. The steps we follow are:

- **Writing the research questions.** We start by defining the following research questions:

  RQ1: How higher education is addressed in Latin America?
  RQ2: How digital transformation is linked to higher education in Latin America?

- **Searching the sources**. We define the sources to be searched for papers/chapters related to this topic. After a preliminary search, we decide to work with the following databases, since they deeply cover the topic: Science Direct,

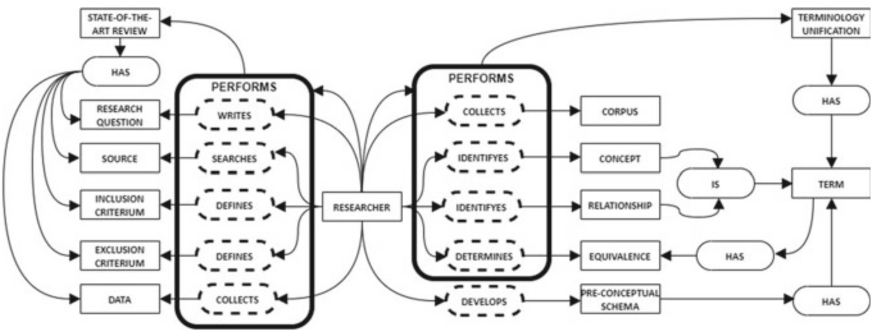

Fig. 2 Method followed for completing the pre-conceptual schema about higher education across the continent (*Source* The Authors)

Springer, and IEEE. Some of the target books/journals/conferences selected are: International journal of educational development, Encyclopedia of international higher education systems and institutions, World neurosurgery, The Internet and higher education, Research in economics, Telecommunications policy, Journal of development economics, Policy and society, Procedia computer science.

- **Defining inclusion and exclusion criteria**. We define some criteria for giving scope to the search process. First, we define as inclusion criteria: (i) five years of publications, preferable closer to 2020; (ii) English language; (iii) analysis of more than one Latin American country; and (iv) some factor related to digital transformation. Also, we define the following exclusion criteria: (i) papers/chapters/books just citing the results of an analysis performed in another paper; (ii) papers/chapters/books excluding the keywords higher education and Latin America from the title/abstract/conclusions; and (iii) availability of the full text.
- **Collecting data**. We obtain twelve studies (Delprato & Akyeampong, 2019; Fischman & Ott, 2018; Gacel-Ávila et al., 2018; Guiroy et al., in press; Hilliger et al., in press; Izaguirre & Capua, 2020; Katz & Callorda, 2018; Lemaitre et al., 2018; Neidhöfer et al., 2018; Sanabria-Pulido et al., 2016; Torres-Samuel et al., 2020; Viloria et al., 2020) after performing the previous steps. We discuss the main contents of such papers/chapters in Sect. 3 of this chapter in order to provide an initial context to the readers and checking the contents are suitable for the realization of our analysis.

4.2 Terminology Unification

This phase includes the following steps:

- **Collecting the corpus**. We use the full text of the papers/chapters identified for creating a corpus related to the holistic view that we are searching for in order to answer our research questions. We exclude from the corpus some information of the papers/chapters to avoid the information bias and focus on the contents: (i) headers and footers, since they are referred to the same information included in the title/authors; (ii) information about the copyright and editorial; (iii) names and affiliations of the authors; (iv) keywords, since not all of the chapters/papers have this information; (v) acknowledgements, declarations of competing interest, and credit author contribution statements, since we are focused on the contents of the papers/chapters related to the topic that we are summarizing; and (vi) references. The final corpus is a plain text with 12 documents. We use an online tool for counting words (https://wordcounter.net/) in order to determine the following features of the corpus: 83,489 words, 2862 sentences, 11,684 paragraphs, 5 h and 4 min of reading time, and 7 h and 44 min of speaking time.
- **Identifying main concepts and relationships**. We use the words and their frequency for summarizing the information of the corpus in the same online tool (https://wordcounter.net/). We omit the usual stop words of the English language,

i.e., definite and indefinite articles, prepositions, and adverbs. We also omit some other words common in technical writing like abstract, introduction, conclusions, paper, chapter, and future work, since they are always present in the documents and they can bias the contents. Finally, we omit some other words related to the way to perform the analysis, like study and survey. After summarizing the most frequent words, we also use the information related to pairs and triplets of words more frequent. Such information is summarized in Tables 1, 2, and 3.

- **Determining equivalences among terms**. Tables 1, 2, and 3 are the terminological basis for understanding the documents incorporated in the corpus. Some words exhibit different kinds of relationships with others. Terminological unification is the process for simplifying such relationships in order to assign some words to other ones as a way to deal with multiple words for expressing the same ideas. We identify the following relationships/problems in the information:
  - Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, and others are names and countries
  - LA is one acronym for Latin America
  - Latin America is also the name of a region
  - University and school are two types of institutions
  - Child and children are students in this context
  - Private and public are affairs associated to institutions
  - Teachers are usually referred in the documents as teaching staff
  - Math, mathematics, language, reading, and others are courses belonging to academic programs
  - Micro and macro are sizes related to the institutions
  - Primary, secondary, and higher are levels of education
  - Digital ecosystem and education are factors of public policies.

4.3 *Pre-conceptual Schema Development*

In this phase, we use the symbols of the pre-conceptual schema (Sect. 2.2), and the information gathered in the previous phases for graphically summarizing the information. Some words are directly used from Table 1, and other ones are related to the terminology unification we perform in the previous phase (terms in yellow in the pre-conceptual schema). Structural relationships "has" and "is" are added as needed. Some other words are added for completing the sense of the schema (terms in blue in the pre-conceptual schema); we extract such words from the documents as follows:

- Improving quality comes from "improving educational quality is a necessary condition to raise school attendance" (Delprato & Akyeampong, 2019, p. 3)
- Narrowing learning gap comes from "in other countries specific school policies can narrow the learning gap" (Delprato & Akyeampong, 2019, p. 14)

Table 1 Single words and frequency in the corpus

Word	Freq	Word	Freq	Word	Freq
Education(al)	631	Teaching	108	Score	69
Latin	528	Services	102	Math	68
Student(s)	444	Model	102	Parental	68
America	371	Missing	101	Argentina	68
Public	347	Institutions	101	Panel	68
Countries	319	Affairs	100	Reading	67
Data	261	Academic	94	Levels	67
University(ies)	255	Policy	92	Effect	66
Learning	211	Private	91	Parents	66
Programs	193	Intergenerational	89	Colombia	66
School	193	Sample	88	Regional	65
Country	190	Support	85	Factors	65
American	185	Household	83	Significant	64
Child	174	Time	83	Institutional	64
Higher	172	Indicator	83	Performance	64
Estimates	165	International	80	Percentage	63
Mobility	165	Group	80	Groups	61
Analysis	156	Urban	79	Terms	60
Development	155	World	79	Variable	60
Level	151	Access	79	Infrastructure	59
Broadband	149	Caribbean	79	Source	59
Research	141	Chile	79	Population	56
Region	140	Labor	76	Classroom	56
Effects	135	Staff	76	Distribution	55
Need(s)	129	Policies	74	Factor	55
Economic	122	Language	74	National	55
Information	117	Brazil	73	Degree	55
Working	116	Characteristic	72	Individual	54
Digital	115	Adoption	72	Value	54
Social	112	Matching	71	Questions	53
Average	111	Impact	71	Home	52
Quality	110	Mexico	71	Internet	52
Index	110	Income	70	Ecosystem	51
Variables	109				

Source The Authors

Table 2 Pairs of words and frequency in the corpus

Words	Freq	Words	Freq	Words	Freq
Latin America(n)	382	Labor market	21	Work indicator	15
Public affairs	95	Work home	21	Research development	15
Higher education	91	Paid work	21	Classroom missing	15
Digital ecosystem	49	Urban rural	21	School level	14
Missing data	48	Parental education	20	Private public	14
Teaching staff	45	Human capital	20	Contextual effects	14
Intergenerational mobility	45	Urban	20	Index mothereduc	14
Affairs education	45	Mobile broadband	20	Economic growth	13
American countries	44	Working children	19	Parental education	13
America Caribbean	44	Educational data	19	Location size	13
Costa Rica	40	Mothereduc indicator	19	American public	13
Child labor	35	Ecosystem development	19	Endogenous effects	13
La services	32	Non-working	18	Demand gap	13
Math reading	31	Child work	17	Intergenerational persistence	13
Matched sub	30	Brazil Chile	17	Student's work	12
Needs la	29	Dominican Republic	17	Matching estimates	12
Peer effects	27	Home unpaid	17	Education institutions	12
Missing values	27	Head master	17	Students teaching	12
La adoption	26	Mathematics language	17	Ideal expectations	12
Years education	25	Public policy	17	Development digital	12
World bank	25	American Caribbean	17	Fixed broadband	12
Significance level	25	Affairs programs	17	Digital literacy	12
Programs Latin	24	Working students	16	Educational background	12
Public private	24	Socioeconomic	16	Supplemental material	12
Isecf index	24	Rural urban	16	Household surveys	12
Indicates significance	24	Public universities	16	Sixth grade	11
Cross country	23	Macro universities	16	Impact child	11
Propensity score	23	American universities	16	Public policies	11
Work outside	23	Development index	16	Indicator work	11

(continued)

Table 2 (continued)

Words	Freq	Words	Freq	Words	Freq
Education Latin	23	Educational attainment	16	Significance levels	11
Academic information	23	Programs public	16	Tertiary education	11
Learning gap	22	Effect work	15	Economic development	11
Outside paid	22	Argentina Brazil	15	People born	11
Public administration	22				

Source The Authors

- College comes from "40% of students annually across the entire region attended private colleges or universities" (Fischman & Ott, 2018; Gacel-Ávila, 2018, p. 89)
- Accrediting academic program comes from "quality assurance systems and program accreditation are in development in some countries" (Gacel-Ávila, 2018, p. 2)
- Achieving economic growth comes from "as a consequence of the rapid economic growth achieved in the last decade" (Katz & Callorda, 2018, p. 675)

Finally, information from Tables 2 and 3 are used for assembling noun phrases used as concepts/notes as follows:

- Digital ecosystem
- Public policy
- Economic growth
- Latin America
- Costa Rica
- Dominican Republic
- Teaching staff
- Learning gap
- Academic program.

The resulting pre-conceptual schema is proposed in Fig. 3. We can use Fig. 3 for analyzing the information related to the documents of the corpus (Sect. 3) in terms of the unified terminology. Such information is summarized in Table 4 by relating the contents of Sect. 2 (column "analysis") ordered by reference to the phrases of the pre-conceptual schema (sets of concept-relationship-concept taken from the schema). The resulting pre-conceptual schema from Fig. 3 is also a conceptual framework for potentially analyzing all of the chapters of this book, since we are providing a unified terminology related to the topics covered by the book.

Table 3 Triplets of words and frequency in the corpus

Words	Fr	Words	Fr	Words	Fr
Public affairs education	45	Programs public affairs	10	Math reading math	6
Latin America Caribbean	43	Sixth grade students	9	Reading math reading	6
Latin American countries	34	Higher education systems	9	Higher education Latin	6
Indicates significance level	24	Mobility Latin America	9	Lumbar interbody fusion	6
Education Latin America	23	Parental education background	9	Mathematics language science	6
Matched sub samples	19	Latin American programs	9	Unctadstat las Eurostat	6
Digital ecosystem development	19	Impact child labor	8	Affairs program Latin	6
Programs Latin America	18	Effect work learning	8	Part time students	6
Urban rural	18	Argentina Brazil Chile	8	Data envelopment analysis	6
Public affairs programs	16	Colombia Costa Rica	8	Envelopment analysis idea	6
Work home unpaid	15	Minimally invasive spine	8	Coordination group work	6
Latin American Universities	15	Needs la adoption	8	Chat instant messaging	6
Latin American Caribbean	15	Ideal expectation scale	8	Search academic information	6
Needs la services	14	Global innovation index	8	Third regional comparative	5
Isecf index mothereduc	14	Work learning association	7	Regional comparative explanatory	5
Work learning gap	13	Brazil Chile Colombia	7	Comparative explanatory study	5
Outside paid work	13	Work outside	7	Explanatory study terce	5
Work outside paid	13	Errors clustered school	7	Impact work learning	5
Rural urban	13	Clustered school level	7	Chile Colombia costa	5
Index mothereduc indicator	13	Peer effects education	7	Middle income countries	5
Latin American public	12	Mothereduc indicator respectively	7	Non-working students	5
Urban rural urban	12	Missing data isecf	7	Head master teacher	5
Public private public	12	Data isecf index	7	Socioeconomic status	5

(continued)

Table 3 (continued)

Words	Fr	Words	Fr	Words	Fr
Private public private	12	International telecommunications union	7	Location size	5
Propensity score matching	11	Infrastructure service quality	7	Countries abbreviations described	5
Classroom missing data	11	Completed years education	7	De Buenos Aires	5
Ecosystem development index	11	American public affairs	7	Economic Commission Latin	5
Child work learning	10	Consulting university services	7	Countries Latin America	5
Child labor learning	10	School head master	8	Need quality feedback	5
Higher education institutions	10	Quantile treatment effects	6	Teaching staff need	5
Students teaching staff	10	Socioeconomic cultural	6	Latin American governments	5
Mathematics language sciences	10	Nonworking children	6	Latin American context	5
Development digital ecosystem	10	Paid work home	6	Analysis educational data	5
Affairs education Latin	10				

Source The Authors

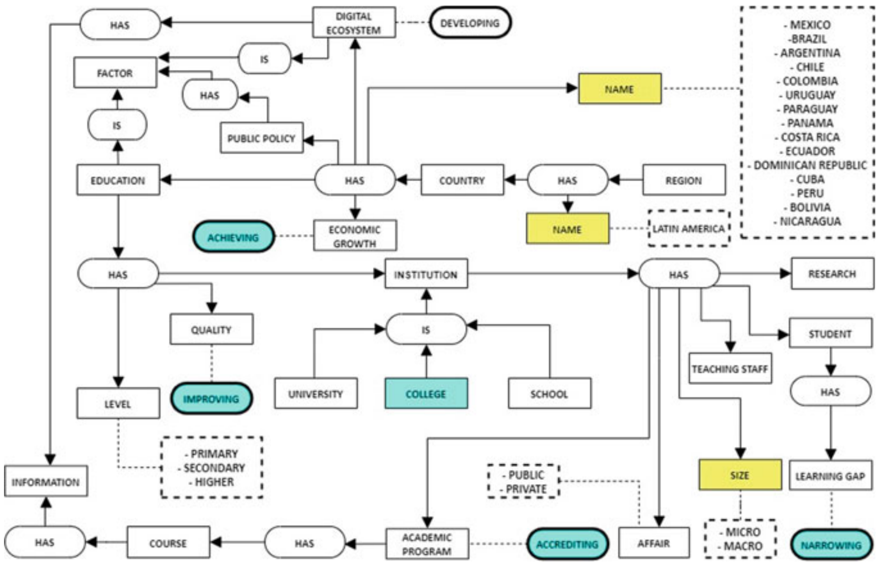

Fig. 3 Resulting pre-conceptual schemas about higher education in Latin America (*Source* The Authors)

Table 4 Analysis of the background documents based on the pre-conceptual schema

References	Phrases from the pre-conceptual schema	Analysis
Delprato and Akyeampong (2019)	Student has learning gap Narrowing learning gap	Students need to improve their skills in order to increase their payments
Fischman and Ott (2018)	Academic program has course Institution has student Accrediting academic program	Accreditation is the way to solve some of the problems related to out-to-date curricula. Usually, the groups resistant to change in Latin American public institutions are hidden among students
Gacel-Ávila et al. (2018)	Accrediting academic program	The way to internationalization is linked to accreditation of the academic programs
Guiroy et al. (in press)	Country has digital ecosystem Country has education	Technology in inserted in the digital ecosystem of the countries. This is the linkage to education
Hilliger et al. (in press)	Institution has student Institution has teaching staff Institution has academic program Academic program has course	The problems are related to different components of the institutions (in this case human resources)
Izaguirre and Capua (2020)	Education has level (secondary)	Problems related to this level of education
Katz and Callorda (2018)	Country has digital ecosystem Country has economic growth Developing digital ecosystem Achieving economic growth	This is an exploration of the relationship between the development of the digital ecosystem and the economic growth
Lemaitre et al. (2018)	Region has name (Latin America) Region has country Country has education Education has level (higher) Country has public policy Public policy has factor Education is factor	There is a close relationship between the concepts mentioned in this paper

(continued)

Table 4 (continued)

References	Phrases from the pre-conceptual schema	Analysis
Neidhöfer et al. (2018)	Region has name (Latin America) Region has country Country has education Country has economic growth	Inequality in education can be explained by correlating the concepts mentioned
Sanabria-Pulido et al. (2016)	Region has name (Latin America) Region has country Country has education Education has institution Institution has affair (public)	The comparison is performed by using a model about public affairs in Latin American institutions
Torres-Samuel et al. (2020)	Region has name (Latin America) Region has country Country has economic growth Country has digital ecosystem	Again, an exploration about the interdependence between economic growth and digital ecosystem in Latin American countries
Viloria et al. (2020)	Region has name (Latin America) Region has country University is institution Country has digital ecosystem Institution has student Country has public policy Public policy has factor Education is factor Digital ecosystem is factor	Analysis of the preferences of the students linked to some elements of the digital ecosystem

Source The Authors

5 Conclusions and Future Work

In this chapter, we proposed a terminologically unified summary about higher education in Latin American countries and the way how it is addressed. The method for developing such a summary started by performing a state-of-the-art review-based on a method for driving systematic literature reviews in software engineering. Then, we conducted a terminology unification process by collecting a corpus with the literature identified and performing an analysis based on the frequency of words, pairs, and triplets of words in order to unify some of the more frequent terms. Finally, we used the information of the previous phases for drawing the pre-conceptual schema and completing some information based on some missing information of the schema by extracting some additional information from the identified literature. We also used the pre-conceptual schema for analyzing the terminology coming from the literature identified and checking the terms can cover the information related to such papers/chapters.

We can recognize—by using the pre-conceptual schema—digital ecosystem and education as factors of the public policies of Latin American countries for improving quality of higher institutions in order to develop the digital ecosystem and achieve the economic growth of the countries. Also, we have important goals in the conceptual framework as accrediting academic programs of the institutions for narrowing the learning gap of the students.

We strongly recommend the readers of this book to continuously check this pre-conceptual schema in order to understand the terminology proposed in the remaining chapters.

Some lines of future work can be defined from this chapter:

- Including more documents to the corpus, in order to check the suitability of the different elements.
- Increasing the number of elements in the pre-conceptual schema for gaining more detail in the conceptual framework.
- Analyzing some other elements to bring more information to the pre-conceptual schema. For example, some action verbs were included in the list of more frequent words—e.g., estimates, impact, and effect—but they were not used as dynamic relationships in the pre-conceptual schema. Some other less frequent elements should be explored like events and specifications.

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A Roadmap for Digital Transformation of Latin American Universities

Sandra Martínez-Pérez and Guillermo Rodríguez-Abitia

Abstract The year 2020 has made it very clear for universities that they need to transform and leverage information and communications technologies (ICTs) more than ever. Disruptive technologies have gained relevance in every aspect of life, altering the traditional ways for work, family and school environments. Thus, Society 5.0, understood somewhat as the humanised focus of Industry 4.0 developments, provides educational institutions with great new opportunities for innovation, as well as pertinence and quality assurance for their teaching and learning processes. This paper describes a comparative analysis on the use of ICTs for education and administrative processes by higher education institutions in five Latin American countries: Argentina, Brazil, Chile, Mexico and Peru. Their levels of readiness to profit from ICTs are diagnosed, as a function of several factors, including technology infrastructure planning and development, digital skills, educational technology planning, and administrative support, among others. The results allow for undertaking a gap analysis, and a roadmap to overcome the challenges for a successful digital transformation process is then laid out, as well as general recommendations for its use. Insights obtained from this study show clearly that many realities exist, not only between countries, but also within. The lack of infrastructure and financial resources represents major deterrents for ICT appropriation, but it is ICT, in fact, the potential solution for reducing digital exclusion.

Keywords Digital transformation · Higher education · Latin America · Comparative study · Education technology

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1 Introduction

Socio-educational, political, economic and technological changes are influencing people's lives, homes, jobs and education. The rapid technological transformations, leading to Society 5.0, point to four key elements to help the system face the new challenges: education, research, innovation and leadership (UNESCO, 2016). In turn, these transformations: offer new ways of relating and communicating; impact and lead to the construction of digital identities; provide new opportunities for innovation and improvement of the quality of health and education systems; provide a diversity of tools for solving problems and making decisions; give the possibility of generating new jobs or reinventing oneself; and acquire skills aligned with current demands and purposes, among others. But they can also unbalance and highlight their limitations, difficulties and lack of work–life balance, encourage their abusive use and generate new social and digital divides as evidenced by COVID-19 (OECD, 2019a, 2020).

The disruption of technologies in organisations points to the need for a digital transformation that leads to new challenges, contributes to their governance and functioning, strengthens their social relationship, responds to the demands of the moment, and promotes digital policies and agendas linked to society in general, and to education systems in particular (Baker, 2014; Ithurburu, 2019).

Events happening in the year 2020 have highlighted the importance of investing in technologies, and implementing policies and practices lead to innovation and redesign of National Development Plans (NDP) and education plans to be in line with the digital strategies and agendas of Latin American countries (OECD et al., 2020).

Throughout this process, universities have played and will continue to play an important role, not only in the promotion of knowledge, the acquisition of skills and the development of innovation, but also in the digital transformation. Higher education institutions, the Universities 4.0, have to commit themselves and connect with their diverse ecosystems (Barnett, 2017), reinventing themselves to respond to the new economies, trends, demands and commitments of a globalised society (Dewar, 2017).

Under this scenario, our objective is to describe, analyse and compare the use of technologies and academic administration processes in higher education institutions in five Latin American countries, in order to shed light on the different factors that influence the choice, availability and use of technologies, identifying where they stand and drawing a roadmap to reach education 5.0.

2 Digital Transformation: From the Industrial Revolution to Society 5.0

Technological advances (artificial intelligence, robotics, extended reality, the Internet of things, cloud computing, open educational resources, etc.) are transforming the various contexts (family, social, political, economic and educational) and scenarios (growth, limitation, collapse and transformation) through which we move and prepare for a fast-approaching scenario (Brown et al., 2020). Focusing on transformation, such scenario implies a wide range of innovations resulting from digitisation (conversion of analogue data and processes into a machine-readable format) and digitalisation (use and interconnection of digital technologies and data that lead to changes or creation of new activities) (OECD, 2019a) which leads us to rethink public policies, strategies and practices in different countries. Also, this allows reflecting on the importance and influence of Industry 4.0, consisting of hyperconnectivity and cyber-physical systems that impact organisations and society (Roblek et al., 2016).

The transformation designed by the United Nations (UNESCO, 2016) implies a change in the paradigm of sustainable development in a new industrial era driven, in turn, by a digital revolution (OECD, 2020). The new intelligent society is characterised by a change in the relationships between citizens, by extensive digitalisation and the use of emerging technologies in order to improve productivity, favour teaching and learning processes, increase quality in work, education and health, promote digital skills and make society more sustainable (Garbellano, 2018; Keidanren, 2018; Rodic, 2017). Thus, the digital transformation invites the use of digital technologies through a process of organisational and cultural change (Almaraz et al., 2016; Baker, 2014).

Under this perspective, higher education institutions focus their efforts on social, organisational and technological aspects to carry out this digital transformation. Benavides et al. (2020) present a complex radar of dimensions of the digital transformation which impacts on universities: teaching, infrastructure, curriculum, administration, research, business processes, human resources, extension, digital transformation governance, information and marketing, which in turn combine with a diversity of actors and methods always in accordance with the three aspects mentioned above: social, technological and organisational. For their part, Rodríguez-Abitia, Martínez-Pérez, Ramírez-Montoya and López-Caudana (2020) identify three essential axes: the technological, the pedagogical and the organisational, which in turn are related to different ways of conceiving technologies: (a) technological one with information and communication technologies (ICT); (b) pedagogical one linked to learning and knowledge technologies (LKT); and (c) organisational one with organisational and collaborative management technologies (OCT). The intersection of the three axes with their respective perspectives provides a new way of visualising the use of technologies under an approach of empowerment and participation (EPT), which allows us to face complex life situations and to develop competences that help us to successfully manage all the challenges that are posed by the new Society 5.0 (OECD, 2019c). Such society that is understood as driven by data, being super-smart and focused on individual needs and capabilities (Mavrodieva & Shaw, 2020). This is a hyperconnected society that requires social change, freeing itself from the underlying problems of Society 4.0, the information society, which is the result of the fourth industrial revolution. Society 5.0 seeks to transform organisations into super-intelligent institutions by means of information and communication tools and technologies (Schwab, 2017), and it opens up new questions, based on automation, dematerialisation, digitalisation, industrialisation and servitude (Salgues, 2018) that modify people's habits, and the economic and political patterns of the system. It also has a radical impact on the nature of an entity, adopting four levels of digital transformation: the productive process, the action model, the domain and the cultural/organisational (Dutta & Lanvin, 2020).

2.1 The Digital Transformation in Latin America

There is no doubt that the digital transformation brings new challenges and improves the functioning of institutions (OECD, 2019b). For this to happen, society as such must acquire skills in line with the vertiginous advances we are experiencing. In this process of change, universities take on a relevant role in the training of digital competences to draw up new scenarios and educational paradigms in relation to current needs (López et al., 2020).

The CEPAL (2018) focuses on the need for strengthening and renewing digital strategies as a part of the digital agenda for Latin America and the Caribbean (LAC) to favour regional collaboration and incorporate and reinforce the use ICT in education, promoting teacher training, innovation in pedagogical models, and the creation of open educational resources, among other actions.

This agenda, linked to the National Development Plans, is a reference for the progress of digital policies, in order to promote the desired transformation, cooperation and integration of technologies in all LAC member countries (CEPAL, 2018; Ithurburu, 2019).

Along these lines, the OECD (2019b, 2019c) and the OECD et al. (2020) draw up a roadmap for the mediation of the digital transformation (Table 1):

In order to chart this route, it is important to be in line with the Network Readiness Index model—NRI—(Dutta & Lanvin, 2020) supported by four pillars: technology, people, governance and impact, which in turn underlies other subpillars (Fig. 1), in order to digitally transform society, and therefore, higher education institutions.

3 Method

As a result of the literature and reference cases review, we identified the main elements that comprise and define the successful application of ICT, LKT and OCT in higher education institutions, and an observation guide was created accordingly. Visits were requested and scheduled for nine universities in five different countries in Latin America.

Table 1 Roadmap for the digital transformation

Dimension	Action
Equip governments with better data and indicators for dealing with the challenges	A1. Make the digital economy visible in economic statistics A2. Understand the economic impacts of digital transformation A3. Encourage measurement of the digital transformation's impacts on social goals and people's well-being A4. Design new and interdisciplinary approaches to data collection
Areas for priority attention	A5. Monitor technologies underpinning the digital transformation, notably the Internet of things, AI and blockchain A6. Improve the measurement of data and data flows A7. Define and measure skills needs for the digital transformation A8. Measure trust in online environments A9. Establish an impact assessment framework for digital governments

Source OECD (2019b) and OECD et al. (2020)

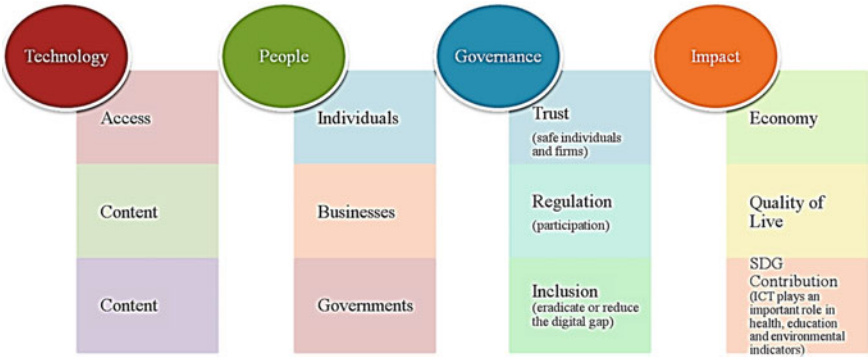

Fig. 1 NRI for digital transformation (Dutta & Lanvin, 2020)

3.1 Sample of Universities

It was sought to reflect a variety of realities that are commonly found in the region, so they were selected strategically based on size, funding source, vocation and location. First, sizes were classified based on the official categorisation from the Ministry of Education of Mexico (SEP-DGPPEE, 2018) mainly as a reference. This categorisation includes four types, according to student enrolment: (1) mega universities with more than 50 thousand students; (2) large universities whose student population

Table 2 Universities in the sample

Institution code	Location	Size	Funding	Vocation
AR-PU-MG	La Plata, Argentina	Mega	Public	General
AR-PU-SM	Buenos Aires, Argentina	Small	Public	Specialised
BR-PU-MG	São Paulo, Brazil	Mega	Public	General
BR-PR-LG	Lapa, Brazil	Large	Private	General
CL-PU-LG	Concepción, Chile	Large	Public	General
CL-PR-LG	Antofagasta, Chile	Large	Private	General
MX-PU-MG	Guadalajara, Mexico	Mega	Public	General
MX-PR-LG	Guadalajara, Mexico	Large	Private	General
PE-PR-ME	Lima, Peru	Medium	Private	Specialised

ranges between 10 and 50 thousand; (3) medium universities with between 5 and 10 thousand students; and (4) small universities with a student body smaller than 5 thousand in total.

Additionally, the selection included also both public and private universities, understanding that they face very different conditions in Latin America, due to the great dependence that public universities have on assigned budget, and the private ones on enrolment to have financial income to operate.

Another important classification item was vocation, distinguishing between universities that offer a wide spectrum of majors, as opposed to those that specialise in a particular discipline, such as business or education.

Finally, all universities were located in countries that constitute leading economies in the region, so that fare comparisons could be made to those in fully developed nations. The distribution of the universities in the study is detailed in Table 2. The names of the universities have been removed for privacy purposes. Names have been replaced with codes that include two characters that identify the country where they are located (AR for Argentina, BR for Brazil, CL for Chile, MX for Mexico and PE for Peru), followed by two characters that indicate the source of funding (PU for public and PR for private) and two characters that refer to size (MG for mega, LG for large, ME for medium and SM for small).

3.2 Field Observations and Visits

Visits were arranged with the authorities of the sample universities, and they were planned to include in-depth interviews with people in at least three key functions: the person responsible for ICT infrastructure provision and planning, the person in charge of curricular development and educational model definition, and professors. The visits included direct observations of different facilities that were directly involved in the application of technologies for both administrative and educational delivery, and support processes. All interviews were recorded, and later codified and interpreted by the research team.

All visits were done face to face, as there were undertaken before the COVID-19 pandemic forced universities to close their facilities. A full day was dedicated to each visit. Follow up e-mails, telephone calls or videoconferencing sessions were used to clarify post-visit doubts that may have emerged during the analysis of the data collected.

The semi-structured interview guides included twenty-nine open questions that were classified in five categories: (1) five questions about university political commitment to technology appropriation; (2) five questions on ICT infrastructure; (3) ten questions about faculty digital an informational skills development; (4) five questions of ICT curricular integration and access; and (5) four questions related to ICT-based educational resources use in the teaching and learning process.

3.3 Maturity Level Determination

From the interviews, data was coded based on how the content related to specific elements in a rubric that was created to reflect the level of maturity of a particular institution in each one of the three technological dimensions. Thus, scores were assigned as a result of group discussions by the research team, and decisions were made to determine where each institution was placed in terms of maturity. The levels included in the rubric were five: absent, incipient, medium, integrated and consolidated. Each level was described in detail in the rubric in terms of what elements were expected to be observed for each level and dimension intersection. A summary is described below. As opposed to other maturity models where the lowest value determines the assigned level, decimal points were used to show partial progress within each level. From the rubric, we performed gap analysis for each institution regarding each dimension. Thus, their particular diagnosis could be obtained, and it was easy to determine the steps that they required to increase their digitalisation level in all dimensions. Finally, a general roadmap for digital transformation of higher education institutions was drawn to serve as a reference model for planning and following up of universities in their own processes.

The maturity levels are integrated as described below:

3.3.1 Absent

At this level, there is no ICT plan and no mention of it in the institutional one. There is a lack of a dedicated unit for ICT implementation and support, and only individual independent efforts may be present. There are no computers provided for faculty and students, no Internet connection and no software acquisition program. There are no units or efforts to build digital skills in professors and students. There is no institutional effort to incorporate LKTs in the teaching process, no online courses and no digital repositories. Digital resources are not being produced in an organised manner. There are no OCTs that promote interaction, collaboration and academic management. There is no specialised software.

3.3.2 Incipient

There is now mention of ICT in the institutional plan, but they do not have a plan of their own. Financial resources are seldom allotted to achieve the goals, or they are insufficient. There is some minimum infrastructure available in some areas, and they are normally dedicated to administrative tasks. There might be some loose computer laboratories in place, but their software might not be all legal. There are some courses offered to faculty members about basic ICTs, geared towards operation and no mention of LKTs. The offer is irregular, and it is based on demand. Software is mostly for personal productivity. There are still no online courses, and some basic ICT courses are offered in some majors. Some software tools for basic managerial tasks are in place. In advanced courses, some specialised software can be found.

3.3.3 Medium

There is mention and resources allocated for ICT projects in the institutional plan. There is now a unit dedicated to ICT support. There are computers and some services available for students. Internet access is sufficient in the main areas, but the coverage is not exhaustive. There is a constant training offer of ICT courses for faculty. Professors have the obligation of getting a certain number of training hours, but the type of courses are their choice. Most majors have a basic computing course, and some have specialised courses. There are learning management systems (LMS) available, but not widely used. There are digital libraries, and specialised software, mainly for majors related to science and technology. There is some degree of digital educational resources, but they are mainly stored in closed course platforms.

3.3.4 Integrated

ICT is included in the institutional plan, and it has a plan of its own. There is an ICT unit that provides support and creates norms. Computers and connectivity are available enough to cover the needs of the community. Software is legal, and there are many agreements with vendors. Courses for faculty are planned based on the existing educational model. Professors are given incentives to take them and apply them to their teaching practice. There is personalised follow-up, and they are encouraged to create educational resources. All majors have ICT courses that are geared towards their disciplinary particularities. All subjects for students include the use of technologies. There are standardised educational platforms, and they are widely used. Digital skills are measured for students and faculty, and plans are established to develop them. There are institutional mechanisms to develop educational digital resources, and financial stimuli for implementing technological and didactic innovations in the classroom. There are many repositories and libraries. Most classes are supported in LMS, and they are integrated with management systems.

3.3.5 Consolidated

The use of ICT is a pillar for attaining the academic and administrative goals laid out in the institutional plan. ICT infrastructure is present in all university facilities. Connectivity is vast, and there are equipment loan services. Classrooms are also equipped to make the most from the use of LKTs. ICTs are centrally governed. Professors have incorporated technology regularly in their classes, and students have the necessary digital skills to aid in their academic performance. Training is focused on educational innovation and specialised tools. ICTs are used intensively in all courses, according to their disciplinary nature. Technology use is transversal in the curriculum. There is multimodality in the course offering. Digital repositories and libraries are used greatly, as well as LKTs available for each knowledge area. Developing digital educational resources and storing them in open repositories is a widespread and robust practice. There are established mechanisms to provide technological support to professors, and they feel comfortable using them. The administration uses learning analytics, facilitated by integrated technological tools. Students are free to choose the preferred modality, always aligned to the educational model.

3.4 Drafting the Digital Transformation Roadmap

Based on the previous maturity levels, a roadmap of actions for a digital transformation transition process can be laid out, as shown in Fig. 2.

4 Results and Discussion

From the data gathered, it was possible to obtain a general panorama of the status of application and vision of technology for each one of the institutions. Later on, scores were provided based on the rubric that was built for that purpose, to determine where they stand in the digital transformation process. We now present an overview of the nine universities by country. These results by no means represent the overall state of affairs of digital transformation for universities in each country. Instead, our aim is to provide a general overview of the Latin American region, as a whole, particularly in countries with certain level of economic leadership within it.

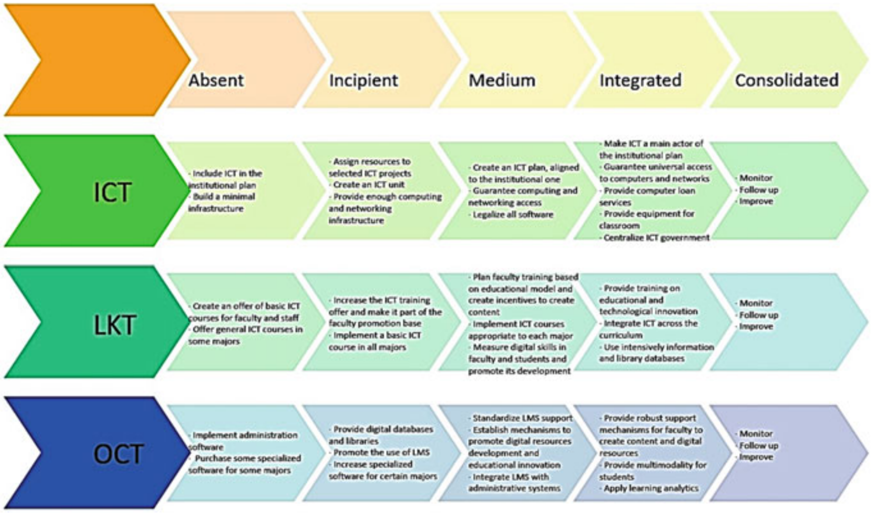

Fig. 2 A roadmap for digital transformation of higher education institutions

4.1 Argentina

The two universities chosen for this South American country are very different in everything but the fact that they are public. One of them is a mega-sized institution with a very wide curricular offer, and a much larger budget than the other, which is small and very specialised in the field of education. The governmental structure of Argentina seems very complex, causing many incentives to be hard to benefit from, in order to build a suitable technology infrastructure. Additionally, the society composition is very polarised, creating great challenges for the institutions to face.

4.1.1 Argentinian Mega-Size Public University (AR-PU-MG)

This university has over 130 thousand students, attending one of more than 100 programs offered. Its development plan mentions the use of ICTs for learning, but this is not made explicit into a particular policy. Support for the use of Moodle as the main LMS is provided, as they prefer the use of open software for ideological reasons. The infrastructure depends on the resources available by each school or faculty independently, so it varies greatly from one to the next. Academic units related to science and engineering are naturals to give higher priority to technology infrastructure than those of humanities and social sciences. This is true both for network connectivity and computing devices.

The area in charge of distance education is also responsible for forming digital skills in faculty members that work in face-to-face programmes. However, this formation is merely volunteer and depends entirely on the demand originated by the professors. They are making efforts to transit to a blended-learning model, not without a great deal of resistance from traditional faculty members. There are virtual spaces and repositories for educational resources. These are validated before publishing. However, there is a great deal of resistance to share resources by the faculty.

4.1.2 Argentinian Small-Size Public University (AR-PU-SM)

This 2-thousand student institution is dedicated to form educators for different levels. It is not strictly considered a university, but it has the same level. Their planning process is not strategically made by the school, but rather at a City and National Government level initiatives, and it includes the appropriation of ICT. However, at times these programs compete with each other, creating barriers for successful implementation, in addition to union-related challenges. Thus, both plans had computer provision programs for students and faculty, leading students to get two different computers, but insufficient Internet access or wireless connectivity available in only a few areas. Also, the curriculum was not designed for the inclusion of technologies yet, despite having some initial work done in that regard.

They have a commercial LMS paid by the federal government. The director promotes the adoption of technologies like Google Classroom but the faculty is not excited about the idea of changing their ways of teaching. Training is provided by the Ministry of Education, particularly on the didactic use of ICTs, with little effect on the actual teaching practice. They lack an effective use of collaboration tools and digital resources repositories, although it is encouraged.

4.2 Brazil

The institutions in Brazil were chosen to reflect two very different scenarios. On the one hand, one of the best ranked universities in Latin America, with a very large student population and very research intensive. On the other hand, a large private institution (not officially consider university by the Brazilian legislation, but recognised as a higher education faculty) that only offers online distance education, and very widely spread all over Brazil, reaching areas that otherwise would not have access to higher education options.

4.2.1 Brazilian Mega-Size Public University (BR-PU-MG)

This university is one of the most prestigious in Brazil and Latin America. It has almost 100 thousand students, a third of which are at the graduate level. Their budget has been guaranteed by a provision in law that binds a certain percentage of the tax collection to it, so the university is not so vulnerable to government changes in priorities. Some ICT services are centralised, while other depend on each faculty or school. There are laboratories and computer loans in every academic unit. They take advantage of free software tools in cloud computing schemes. They encourage the use of Google and Moodle.

Faculty training varies considerably, and it depends entirely on each academic unit. There is not a program at the institutional level. Professors produce their own content. When there is a special project, professional video production is provided. They believe distance education should be strongly based on classes on videos. They are freely available in the university portal and in YouTube. There are certain administrative systems that are centralised, like payroll and registration. However, there are no specific collaboration tools at a central level.

4.2.2 Brazilian Large-Size Private University (BR-PR-LG)

This educational institution is a private online system that serves over 35 thousand students, and it is distributed in 134 sites, all over Brazil, where students can also do face-to-face activities like exams and final project defences. Their business model is based on local alliances and partnerships. Being almost fully online, technology planning is a fundamental part of their strategy. All sites have computer laboratories and are connected to Internet. Digital educational resources are placed within courses in Moodle, and they are stored both in their data centre and in the cloud. They provide all necessary software to their students.

Faculty training is centralised, and it starts upon hiring. Depending on the degree of the professor, they can become content producers, and they may be in charge of recording classes, in short videos, for the use of the whole academic community. This role will require extra training. Courses are departmental, and they are created with the help of a production team that includes graphic designers and education specialists.

They have an integrated administration system that is also linked to their academic control and delivery systems, as well as an Intranet and a pedagogic system. The communications and information flows are very well designed and supported. They do not use all the LKTs available since their business model does not require it.

4.3 Chile

The two universities included in the study are very similar in size and vocation. They are geographically distant, and one is public and the other one private. They both enjoy a very good reputation and are considered research intensive. The main difference is probably in the economic level of their students, posing specific challenges for the public one.

4.3.1 Chilean Large-Size Private University (CL-PR-LG)

This 12-thousand student university in Northern Chile considers technology appropriation as one of any generic competences that their students need to develop. They have a centre in charge of promoting educational innovation and technological support to the educational process. General productivity software tasks are performed in the students' own devices, and they do not provide computer loans. They, however, have specialised software and laboratories to aid many disciplinary areas with top technology, greatly based on alliances with vendors. Network access and availability is quite satisfactory.

They provide training and mentoring for faculty members to appropriate technology and facilitate the learning and teaching processes, as well as to successfully apply their competence-based curricular design. Nonetheless, this service is completely based on demand, and it is not mandatory for faculty members to engage in this activity. In fact, there are no extra stimuli to do so, therefore limiting their participation. The main base technology for interaction and collaboration is the virtual spaces in an LMS. There are no repositories for digital resources or any other type of community-building support.

4.3.2 Chilean Large-Size Public University (CL-PU-LG)

Just like its private counterpart, this university serves around 12 thousand students. However, these students do not necessarily have their own computing devices or Internet access at home, so they provide laptop loans, and access to computer laboratories, with both general and specialised software. The university does not have an explicit mention of technology in its educational model, although it refers to serving a changing and challenging society. Wireless network access seems to be enough for the needs of the academic community, at least in the main building areas.

There is not a specific organisational area to provide pedagogic and technological support for faculty members to innovate in their teaching tasks. The curriculum includes technology courses, varying greatly to accommodate disciplinary needs. They build their own administrative systems, and they are very well integrated with the academic platforms, including Moodle and G-Suite. They do not have a repository for digital education resources, but collaboration is highly encouraged to produce them.

4.4 Mexico

Both universities in Mexico are in the same city, which is the second largest in the country. It is an area with a reasonably high level of development compared to other regions in the country. Thus, it is expected that they will somehow reflect the highest quartile of the universities in the nation with regard to advancement in the digital transformation process. Any challenges they face must be greater in less developed areas.

4.4.1 Mexican Mega-Size Public University (MX-PU-MG)

This university is one of the largest in the country, with more than 270 thousand students in different levels. It is also very highly recognised, and it is organised in 15 university centres, depending on discipline or region in the state. ICTs are mentioned in the university's development plan as a means for managing information and learn online. Certain norms and policies are issued and enforced centrally through a university-wide ICT function organisational unit. They provide computing infrastructure through 288 computer centres with more than 60 thousand computers. They, however, lack loan services for devices to be borrowed by the students. Most of the areas are connected to the university network directly, and in few cases, they hire an external carrier. Nonetheless, the bandwidth is insufficient at peak times, due to the large amount of concurrent users that need this service.

There is availability for providing virtual spaces in learning management systems, Moodle being the official one, to those professors who request it. They offer face-to-face and virtual programmes, but they rarely mix. There is a centralised training effort for faculty to build digital skills, foster educational innovation, learn specific LKTs, and discipline-specific technologies.

Finally, there is an integrated academic system. The university provides help to faculty members who wish to develop digital educational resources, and there are well consolidated repositories. There are no specific collaboration systems in place.

4.4.2 Mexican Large-Size Private University (MX-PR-LG)

This 13-thousand student university is very well covered regarding ICT infrastructure. Technology plays a very important role in the strategic plan of the institution, as a means for educational process transformation with a student-centred model. Even though they do not provide device loan services, students use their own, and there is plenty of computers available in laboratories. The use of blended-learning models is widespread, aiming at maturing into the creation of learning communities online.

Faculty training is expected to be self-directed. However, they have a centre for online learning where they can access several courses to improve and innovate the teaching process. The use of technology in class is made in a tacit manner, assuming everyone has digital skills.

For LMS, they use both WebCT and Moodle. There is a continuous collaboration with technology vendors, and they tend to create virtual communities to foster collaboration between faculty and students.

4.5 Peru

For the Peruvian case, we chose a private university, with very good reputation, and specialised in the Business areas. There is no choice of public universities in Peru, and that is a limitation, though it is expected that they will have a performance similar to their counterparts in other countries in the region.

4.5.1 Peruvian Medium-Size Private University (PE-PR-ME)

This university started as a Business Graduate School. Even when it has expanded to offer undergraduate programmes, its main core is still the graduate level. It serves close to 8 thousand students, and it has its main campus in Lima, and some continuing education and extension sites in other cities in Peru.

Computing and telecommunications infrastructure is deemed sufficient, though it can always be improved. The use of virtual technologies is more appropriated for continuing education classes. Graduate programmes professors are more resistant to change, but this is likely changing greatly due to the COVID-19 pandemic. In continuing education, faculty training is constant, and they climb levels of accreditation. There are also workshops and incentives for content creation, though the resources created are rarely shared, but rather used in the classes of the author. Training for traditional courses is not continuous, and it needs to be reinforced.

They use Blackboard and Moodle for different modalities of their education, but they are currently migrating from the former to Zoom. It is estimated that 90% of the interaction between students and faculty occurs with the use of these technologies, and some additional support ones. They combine virtual and face-to-face options, allowing for flexibility in a complex metropolitan environment. All administrative systems are centralised, and they are now implementing an integrated system. All courses are automatically created in Moodle. These are connected to the administrative systems, and much of the resources reside in the cloud.

The results from the different countries and the overall regional gap analysis are depicted in Fig. 3.

5 Conclusion

Transiting towards a successful digital transformation seems to be a straightforward but not easy enterprise. Institutions in Latin America, particularly the public ones, have to strive for an effective technology use to help them provide quality education, while dealing with high uncertainty levels, volatile environments, and complex bureaucratic systems.

The situation observed in all private institutions seems to be quite similar, regardless of the country. This may mainly be because of the high economic level of their

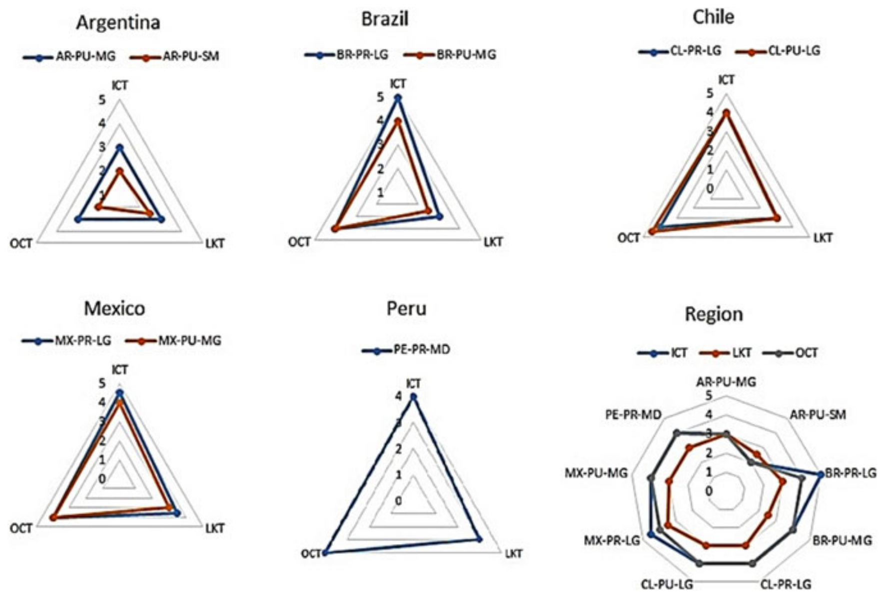

Fig. 3 Gap analysis by country, and overall results

student population, which makes things easier on the institution, not having to worry about digital exclusion circumstances as much as their public counterparts. For them, it is a priority to build a good branding through the effective use of technological resources. In Chile, the difference between public and private institution is not as notorious, provided that they are both eligible for governmental founding.

Mega universities with great budgets are more prone to have a higher level of digital transformation maturity, but they face a great problem for providing full coverage to their extremely large populations.

There is a hint of correlation between the levels of digital transformation maturity of the Latin American universities with the position where their respective countries rank in the NRI. This index shows interesting information about the different factors that affect the quality of education and the ability of these countries to meet the SDG set by UNESCO (2016).

The universities treated in this study are considered, for the most part, to be on the high rank compared to the others in their own nation. Therefore, all aspects reviewed here could be expected to be lower for the overall universe of institutions.

The roadmap for digital transformation proposed can serve as a good starting point to diagnose the current status of an institution and provide the steps that need to be followed to move towards a successful digital maturity level.

Further analysis is in order to include institutions in less-advantaged economies, where inequalities are steeper, and challenges must be greater.

Only through a well-planned innovation and digitalisation strategy, that can overcome severe structural and bureaucratic barriers, institutions in Latin America will be able to leverage and profit from an intelligent technology use that guides them to provide the quality and pertinent education that the region so desperately needs to foster development.

After this brief X-ray, one of the key ideas emerging from this whole panorama of Latin America in terms of digital transformation is the importance, as dictated by the OECD (2019a, 2019b, 2019c, 2020), of designing and implementing public policies in accordance with good strategic planning and in line with National Development Plans (NDPs) and digital agendas.

Thus, the fourth industrial revolution is taking us to the foundations of Society 5.0. Despite the technological advances in the lives of individuals and societies, and the substantial changes in LAC, there are still major deficiencies related to Internet access, affordability, organisational infrastructures, skills acquisition and digital training. Hence, the importance of carefully and consciously drawing up the roadmap for digital transformation in society and in the universities.

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Virtual Education in CEIPA: New Educational Paradigm at the Beginning of the Twenty-First Century

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Abstract The CEIPA Business School is a Colombian higher education institution, characterized by providing different education models in the country since its inception. For this reason, CEIPA became the first university institution that created and offered virtual programs in the City of Medellín, and today, it has the largest ratio of the number of high-quality virtual programs in the country. From its first steps in virtual education, since 1996, CEIPA recognized the importance of developing together the virtual education and its own pedagogical model based on problem solving, which allow achieving the learning objectives of its students, understanding the educational process as a whole, in which didactics and teaching methodology cannot be separated. This chapter is aimed to show the case study of CEIPA in the transformation of its graduate and postgraduate programs into digital environments, which shows the changes that were necessary to develop in its academic and administrative process to respond to this new education model, which was a pioneer not only in its beginnings but also in times of the COVID-19 pandemic, spotlighting its success and positioning CEIPA as a leading institution in high educational Colombian´s sector.

Keywords Virtual education · Pedagogical mode · Problem-solving-based learning · Digital transformation

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1 Introduction

Universities in Latin American face great challenges related with the pressure of adopt new information technology (IT) (Hernández et al., 2015) that, as an expression of the knowledge society (Tünnermann & De Souza, 2003), they impose dramatic changes on those educational institutions that remain adopting traditional paradigms related to presence, knowledge petrification, dependence on the teacher's discourse, absence of autonomous and independent work on the part of the student (Bialakowsky et al., 2012), which are characteristic aspects of the imaginary of classical Greece such as the paideia (García, 2013), the Stoa and the academy (León, 2008), as well as the focus of the magister Dixit and its role in indoctrination (Sanz, 2009), the medieval monastic and cathedral approach (Pulido, 2018) and the university models that emerged in Germany, France, England and North America (Borrero Cabel, 2008), in which an elitist sense of superior education prevails a reflection of the social pyramid of knowledge (Jaramillo, 2011).

In Latin America, higher education is a public asset of a social nature, a human and universal right and a duty of the states that leads to the conviction that the access, use and democratization of knowledge are a social, collective and strategic asset, generator of quality of life, full citizenship, social emancipation and regional integration (UNESCO, 2018). In this regard, virtual education is a powerful tool to achieve higher levels of coverage, inclusion and interaction leading to social and active learning experiences based on innovation (Gregory et al., 2016). It is also a means for the university to extend its actions to regions where it is not possible to access in the classroom mode. In other words, universities must face challenges and barriers to carry out the transformations that allow moving them into the virtual world (Morrison-Smith & Ruiz, 2020).

Virtual education and specifically distance learning (online) has been established in the agendas of public policy in the Latin American region as a strategy for closing the digital gap with the developed world, achieving acceptance in many work environments, mainly in the government, the high-tech segments and the academic world (Patru & Khvilon, 2002), boosting gender equality (ECLAC, 2017) and opportunities (Rodríguez & Ana, 2014). In addition, information and communication technology has made it possible to rethink higher education from the perspective of contributing to the reduction of social inequality indicators (Kromydas, 2017).

The COVID-19 pandemic accelerated a latent process of university transformation; indeed, remote education has allowed these organizations to remain active in times of crisis and uncertainty (Bozkurt, 2020); this conjuncture forced an expected reengineering, since the pandemic affected and continue affecting all actors in the educational process: for students the disappearance of the face-to-face relationship; for teachers the challenges of IT in their traditional teaching practice; for service personnel the imminent reduction of jobs; for administrative personnel the challenges of organizational-financial viability and the provision of resources (IESALC-UNESCO, 2020). However, this problematic situation has become an opportunity for universities, as this accelerated transformation is allowing them to adjust its functioning to the trends in demand for education in one of the most unequal regions of the world (Mitchell, 2020).

This chapter presents the case of the digital transformation of the education process in CEIPA Business School, as a proof of the importance of a future vision and an organizational design resulted of the time anticipation (Godet & Durance, 2011). Its founder, Antonio Mazo Mejía, in one of his books, refers to the educational model of CEIPA from the perspective of building future (Mazo, 2013) and set up a pedagogical model oriented to the new realities of higher education more than two decades before the public policy of virtual educational in Colombia (CEIPA Business School, 2020a, 2020b). This has allowed CEIPA to be a pioneer in the Antioquia region and in Colombia in terms of high-quality accredited virtual programs.

This chapter is structured in five sections: The first one presents the methodology used to develop the case study, followed by the theoretical framework related to virtual education in the context of higher education, which is necessary to demonstrate the relevance of virtual education. After this, the CEIPA pedagogical processes associated with the virtual education is presented followed by the CEIPA virtual model and the results obtained in the institution in relation to the experience of this model. Finally, the conclusions of the case study are presented.

2 Methodology

The case study method allows to identify patterns of behavior and unique organizational styles that can be referents in the context of good practices. It is a pragmatic and flexible approach that allows a comprehensive and deep understanding not only of issues and problems, but also of contextualized realities and phenomena (Harrison et al., 2017). This is a research tool that allows knowing and understanding a phenomenon from various perspectives with techniques such as triangulation to give a sense of objectivity to perception. This methodology can be understood from a qualitative perspective because it allows reaching broad understandings of meaningful meanings for privileged actors and witnesses (Stewart, 2014). From a quantitative perspective, it is also possible to develop data analysis that facilitate a systemic view of the problem and its context (Miles et al., 2014).

In the construction of this case, which presents the digital transformation of the educational programs of CEIPA Business School, the following methodological route was taken into account:

- Selection of the case and definition of objectives and purposes. This case has been selected for being the pioneer in Medellín and Colombia of virtual education and for being the institution that has the largest number of high-quality accredited virtual programs.
- Definition of relevant topics and aspects for the gathering of information, as well as the definition of relevant sources of information. In this sense, aspects such

as historical milestones of evolution, philosophy and conception of education, pedagogical model, virtual approach, institutional performance indicators were considered.

- Analysis and interpretation of information and generation of results. For this step, several information sources were used which include CEIPAS databases of students performances, the Colombian professional test (Saber Pro) statistics, CEIPA history documents and interviews with relevant actors such a founders, directives and staff were analyzed. The process of qualitative analysis of conceptual induction and identification of critical success factors of the organization is carried out.
- Preparation of the report. A qualitative and quantitative synthesis of the information is carried out.

3 Virtual Education in the Context of Higher Education

Information and communication technologies, as a functional productive system of humanity, have facilitated the social dynamics of innovation (Ávila, 2013), and in this process, they have opened the way to virtualization which, understood as a wide range of applications and implementations (Scroggins, 2017), and as one of the characteristics of cybersociety (Bell, 1973; Joyanes, 1997; Touraine, 1976), it has impacted one of the institutions most reluctant to change, such as the universities. At the beginning of the twenty-first century, in the virtual campuses of universities of the USA and the UK, there is no generic model of virtual university; however, it is possible to identify some success factors, such as the courses taught, the nature of the local and remote students and some institutional aspects (McConnell & Harris, 1997). Today, in an advanced phase of the knowledge society, and thanks to technological progress, higher education has been able to count on virtual mediation to generate new work environments and support the task of expanding, prolonging and enhancing the intellectual faculties of the human being as proposed by Silvio (2000) at the beginning of this century. Indeed, thanks to this process, in high-demand contexts, virtual education is a great alternative for non-traditional universities (Sim et al., 2004), since through virtual education it is possible to achieve flexibility from the perspective of the student, the teaching, management and expansion of the offer (Sagheb-Tehrani, 2009).

The virtualization of higher education in Latin America is given by paradigmatic convergence between the management of innovation to strengthen the institutional framework and the ecosystem of Information and Communications Technologies to generate futures; It allows updating educational methods and dynamizing economic and social life beyond education (Chan Nuñez, 2016). Virtuality, first disclosed as artificial reality (Krueger, 1970) cited by Ma and Choi (2007), is the combination of software and hardware by developers to create devices (Riva & Mantovani, 2012) and can be understood as a representation of the real world and its transformation into knowledge and information devices. It is an action of participation in a synthetic environment (Mazuryk & Gervautz, 1999) and with possibilities of interaction, as happens in the digital society (Lévy, 2007). In this dimension, reality is virtual, augmented (Schnabel et al., 2014) and mixed. In these dimensions, it is possible to experience presence and immersion in communication (Bohil et al., 2009).

Virtuality has a great scope in the transformation of human life and in general in social practices. It has facilitated data architecture and visualization; modeling, design and planning; training and education; telepresence and teleoperation; cooperative work; entertainment (Mazuryk & Gervautz, 1999); and the practices of higher education with a high transformative impact of paradigms and models firmly established for centuries.

Virtual environments have been established as teaching and learning spaces and have generated learning communities to stimulate the relationships of teaching, research, extension and administration, with networks and flows of factors and actors at a global level (OECD, 2009). Regarding didactics, virtual education has radically transformed practices (Hu-Au & Lee, 2018), because with the integration of IT, access to information and evidence is faster. In addition, through artificial intelligence, it allows the access to information and accelerates the learning process to use tools and instruments more easily for all actors in the educational process. In general, virtual education has facilitated an active education and as well as the implementation of educative models based on learning by problems and by projects (Marquez López & Jiménez Rodrigo, 2014).

4 The CEIPA's Pedagogical Model

From its conception, the virtual educational model of CEIPA goes beyond the simple integration of information technologies to pedagogical processes and is more about the philosophical principles which are expected to be embraced for all the stakeholders. This requires background elements that allows that the essence of the educational process will continue regardless if the education process is carried out in classrooms or virtually. For this reason, CEIPA has been one of the pioneering educational institutions in Colombia both in the way of teaching through different education models (CEIPA Business School, 2020a, 2020b) and in the virtualization of its programs.

The CEIPA's pedagogical model in its update for 2018 seeks to respond to the challenges of the twenty-first century, specifically, to the fourth technological revolution and to the demands of the Colombian Higher Education System (CEIPA Business School, 2020a, 2020b).

In its Institutional Educational Project, to respond to the demands of the future, CEIPA considers as triggering factors of its transformation to the fourth technological revolution, the destruction and permanent creation of new fields of work (jobs), the accelerated obsolescence of skills and knowledge, the new paradigms of production, the risk of greater inequality, the overlapping of eras, the accelerated degradation of the biosphere and the social sphere (CEIPA Business School, 2018, pp. 5, 6). To respond to the normative requirements of the Colombian education system, CEIPA tunes the design of its organizational and governance model (CESU—Consejo Nacional de Educación Superior, 2017) and the design of the pedagogical model with the strategic map of Colombian higher education (CESU—National Council of Higher Education, 2014), based on its guiding principle to give "step and meaning to the inclusion of virtual education to organizational and personal development, to the generation of i-Future" (CEIPA Business School, 2018, p. 7).

The principles in which the CEIPA's pedagogical model is based on are the following:

The beginning in the future: a strategic anticipation. Every action carried out by CEIPA is defined by its strategy plan, which corresponds to a view to the future that want to be achieve by the institution. This future anticipation is oriented toward a different education that, by transcending instruction and the transmission of knowledge, tends to generate "the integration theory-practice-reality in each and every one of the educational programs"(CEIPA Business School, 2018, p. 3).

The Guiding Principle: the train as a living metaphor. This principle, which is present and future, leads CEIPA to define itself as a company that manages "managerial knowledge in classrooms and virtual environments; committed to the development of people and the organizations, the promotion of entrepreneurship and comprehensive education, walking with its clients to generate i-Future. The life projects of its members are the train, moved by fractality; the goal is personal fulfillment; the rails are suitability and integrity, which must be flexible. It is a living metaphor by promoting imagination, innovation and knowledge (Ricoeur, 1975).

A principle that is present and future: dynamic character of reality. It always implies a positioning in diverse realities, which require the generation of academic and administrative dynamics with a high capacity for response and adaptation; it is the starting point for the institutional development and for academic and administrative management. This is the articulating axis of the education, research and relationship methods with the external sector (CEIPA Business School, 2018).

The blue ocean: coherence as a conviction: a commitment to innovation. This principle generates in CEIPA the necessity of a continuous benchmark for organizational management and for the design of its education processes. This is an unavoidable factor characterized by its commitment to innovation and building the future. More than competing with rivals, it is the ideation and creation of new conditions and realities.

A different education for a new context: historical commitment. This principle considers it necessary to articulate theory and practice, knowledge and reality, Being and Doing. CEIPA is oriented toward learning by doing, problem-based learning, contextual and collaborative learning.

Virtual education as a project: overcoming space–time limits. Virtual education is a mechanism to overcome both spatial and temporal limitations, which could hinder or limit the interaction between educational actors (students and teachers). This is a differentiating bet with the aim to promote and qualify the insertion of students and teachers in a world of knowledge increasingly plural, technical, full of tools, content and information. (CEIPA Business School, 2020a, 2020b).

Organization and management: a form of governance in creative disruption. CEIPA bases its planning in the clarity, agility and efficiency as well as on the values of integral development of people, through which all actors can show a high sense commitment to high quality education with a future condition. The income statements are a clear proof of its capacity for self-regulation and sustainable management.

5 CEIPA's Virtual Model

The virtual education model of the CEIPA Business School is comprised of several elements that have been developed since 1996, making it the first university institution in Colombia to venture into this type of mediation. The CEIPA's virtual model has focused on asynchronous communication, allowing interaction between students, academic staff, administrative staff through the resources available in the virtual field of CEIPA, known as i-campus (Boada, 2016), as well as in the synchronous interaction through chat rooms, videoconferences and chats (Boada & Cardona, 2017).

The virtual campus (i-campus) is the way by which technological tools are made available to students and other personnel involved, but it goes beyond a simple repository of tools; it is a work scheme and interrelation between the members of the educational process with the materials and applications, in a context of responsible and ethical work (Mazo, 2011). This system is the center of the virtual mediation process and is complemented by other elements which are described below:

- **I-Campus**: On this platform, students and collaborators access to the available services and applications. Through this, students and teachers access to other applications such as Brightspace academic platform, the request module, e-mails, virtual library, Socrates academic management software, among others. Employees also access this platform, being able to access different applications for managing the academic and administrative process, such as Brighstpace, commercial management, Socrates, administrative repository website, improvement management system, among others.
- **Brightspace Academic Platform:** Through this platform, students and teachers access to the institutional training center, from any place and device with Internet access. The platform allows to work offline and subsequently synchronize to update the work done and upload it to the cloud. The platform has a mobile application, the Brightspace Pulse app, which allows students and teachers to access the platform and be aware of important updates such as news, due dates, grades, among others.

- **Academic and Administrative Management System—Socrates**: This platform allows the operational, administrative and academic management of the institution. In it several processes are carried out, for example the enrollment processes of the students, the entry of grades by the teachers or the reports generation by the managers, among many other tasks and activities.
- **BAMM Virtual Library System**: This is the platform that houses all the bibliographic resources of the institution; it includes virtual and physical bibliographic material and is also in charge of managing the loans and reserves of books, magazines and other materials.
- **Request Module**: This is an application that allows the administration of the requests that students can make. Any request that a student requires must be made through this system as it is accessed through the Internet.
- **Financial, accounting and human management applications**: This applications centralizes this managerial processes, and only people with the profiles to manage these aspects in the institution have access.
- **CEIPA Improvement Management System—SGM**: This system allows the administration of the quality management system, allowing the centralization of the management and monitoring of preventive, corrective and improvement actions, as well as the programming of internal audits to the institution processes.
- **Microsoft Suite**: With this, both students and collaborators have access to the resourcesMicrosoft Office 365 for proper academic and administrative performance.
- **Microsoft Teams**: This is part of the agreement with Microsoft and is used for the administrative management into the institution, allowing teachers and administrators interact through the meetings and video conferences that can be carried out in this system.
- **Zoom**: This application is used for synchronous sessions between students and teachers, allowing academic communication and the development of lectures, conversations and meetings between these actors.
- **Administrative repository** Web site: It is part of the i-campus and is the platform that serves as a repository for all the institution's information.
- In addition to these tools, the institution has other applications that allow the improvement of administrative and academic processes, such as Respondus and Urkund to ensure the quality of the delivery of student assignments or the KM module that allows to do management of training processes in companies or other institutions.

These systems and applications are interrelated in an academic and administrative management model as presented in Fig. 1, allowing the institutional processes to function efficiently, facing students, teachers, collaborators and academic programs and also allowing improving the traceability of information, the interaction between systems/applications, the systematized management of documentation, curricular management and academic quality, among other characteristics. This figure shows the applications that are purely academic or administrative, as well as some that serve functions at both activities.

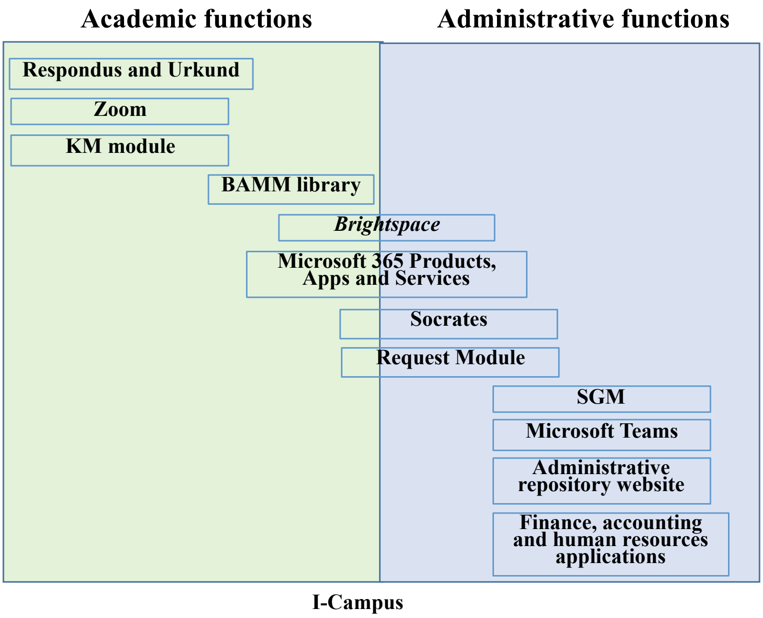

Fig. 1 CEIPA's virtual model scheme. *Source* Own source

6 Results of the CEIPA's Virtual Model

With the aim of evaluating the performance of the CEIPA's virtual model, the information from two sources of information is analyzed. The first comes from the quality self-assessment developed each year, and the second the results of the state exam to measure the competencies of the country's students (ICFES, 2020).

Regarding the self-assessment measurements, it is necessary to first consider the aspects of the pedagogical model that play a determining role in the quality of the virtual model. Table 1 presents the results of the appreciation of various aspects of the pedagogical model consulted with students, both undergraduate and postgraduate, finding that, in all the evaluated criteria, the score was between high and very high in more than the 90% of the consulted students, attesting to their satisfaction in the knowledge acquired, in the appropriation and in the recognition of the usefulness, timeliness and relevance of the pedagogical model.

In a similar way and with the aim of analyzing the degree of satisfaction of students and teacher according to the elements of the virtual model, they were consulted about the quality of the technological tools available in the institution for this purpose. Table 2 shows the results of the assessment on technological infrastructure and digital media for these three types of audiences, finding that satisfaction is high or very high in at least 89% of students, while 95% of the teachers value as very high or high the quality of the technological tools and infrastructure they use for the development of their teaching, research and social projection activities.

Table 1 Results of the evaluation of the pedagogical model

Evaluation of the institutional pedagogical model						
		Very high	High	Low	Very low	NS/NR
Quality	Undergraduate	1.436	1.609	148	37	71
	Postgraduate	193	238	18	1	11
Relevance	Undergraduate	1.371	1.694	129	32	75
	Postgraduate	192	240	17	1	11
Flexibility	Undergraduate	1.429	1.559	200	44	69
	Postgraduate	188	240	20	2	11
Importance for professional development	Undergraduate	1.540	1.529	117	36	79
	Postgraduate	205	236	7	1	12

Table 2 Results of the assessment of technological infrastructure and digital media

Evaluation of the quality of the technological infrastructure and digital media for education, research and social projection						
		Very high	High	Low	Very low	NS/NR
Quality	Undergraduate	1.345	1.604	146	27	179
	Postgraduate	189	242	14	1	15
	Teachers	102	74	5	0	1

Once the perception of the tools is known, it is necessary to analyze the content hosted on the platform for the education process. For this purpose, the students were consulted about the academic and institutional information available virtually and about the quality of the educational media for the development of the education processes, in different aspects as observed in Tables 3 and 4.

In Table 3, it can be seen that in all aspects at least 93% of the students consider that the quality of the information available is high or very high in relation to its timeliness, accessibility and relevance.

Table 3 Perception of academic and institutional information available virtually

		Very adequate	Adequate	Poorly adequate	Inadequate	NS/NR
Upgrade	Undergraduate	1.473	1.621	87	16	105
	Postgraduate	192	241	9	1	18
Accessbility	Undergraduate	1.462	1.616	102	20	102
	Postgraduate	189	245	7	3	17
Relevance	Undergraduate	1.423	1.652	90	23	114
	Postgraduate	188	250	4	1	18

Table 4 Perception of the quality of educational media for the development of training processes

		Very high	High	Low	Very low	NS/NR
Bibliographic material	Undergraduate	1.455	1.600	113	22	111
	Postgraduate	190	233	11	1	26
Audiovisual media	Undergraduate	1.411	1.610	167	18	95
	Postgraduate	175	240	15	1	30
Digital media for virtual education or as support for the face-to-face modality	Undergraduate	1.429	1.587	145	28	112
	Postgraduate	185	234	14	2	26
Specialized software	Undergraduate	1.301	1.598	186	42	174
	Postgraduate	183	223	19	2	34

Table 4 shows that at least 90% of undergraduate and postgraduate students consider that the quality of the bibliographic material, digital media and audiovisual media available for virtual education are of high or very high. Regarding technological tools, this perception falls to 88%, which is satisfactory, but represents an opportunity for improvement in this aspect, and can be solved by acquiring new specific technological tools for the programs offered by the institution.

From the above, it can be inferred that the perception of the quality of the resources available in the institution for the virtual educational process is high. However, it is necessary to analyze the results of the student education process through a standard that allows evaluating the quality of virtual training processes and comparing them with the classroom ones. For this, the analysis of the Saber-Pro tests is carried out, which is the Colombia Quality Examination of Higher Education test, which are applied to all students who are finishing their undergraduate studies (ICFES, 2020). These tests are a necessary requirement imposed by the Colombian government to obtain the professional diploma in the country. The saber Pro tests seek to measure the competences of the students in relation to the area of knowledge studied, considering a set of general and specific competences of the undergraduate programs (ICFES, 2020).

This exam was carried out on the students of the CEIPA programs and the information for the generic competences evaluated from 2013 to 2016, both for the virtual and classroom modalities, is presented in Fig. 2 (Boada et al., 2018).

In Fig. 2, it can be seen that virtual students have lower performance than classroom students in English, while in the other competences, the results are very similar or virtual students exceed classroom students, which allows to conclude that with respect to the general competencies it cannot be argued that classroom or virtual education in the institution is better than the other. However, compared to the national average score that corresponds to the brown line located in the rating of 2.5, CEIPA students always exceeds the national level, which shows the success of the quality of virtual education in the institution. In relation to the specific competences for the

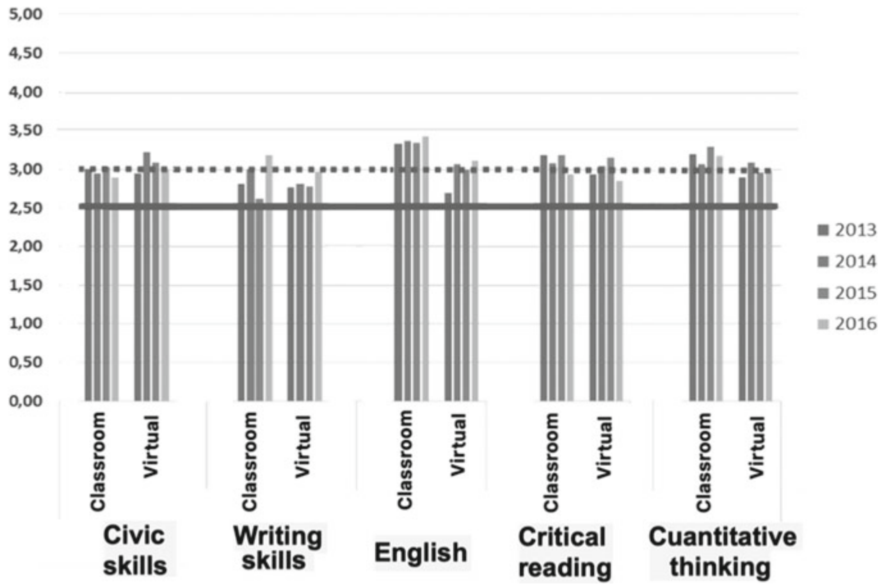

Fig. 2 Results of Saber-pro years 2013–2016 for virtual and classroom students. *Source* Boada et al. (2018)

undergraduate programs offered by the institution, the results of the Saber Pro tests for the same years are presented in Fig. 3.

In Fig. 3, it can be seen that it is not possible to determine a trend that indicates if the level of competences in virtual programs is lower or higher than the classroom students, allowing to argue that virtual and classroom educational processes are equally competitive, demonstrating in this way the success of the virtual educational model of CEIPA. This argumentation is solidified by the fact that, in all cases, the value of the specific competences evaluated is always higher than the national average, denoting once again the quality of the CEIPA virtual educational process as a result of the pedagogical model and the virtual model developed for more than two decades.

7 Conclusions

From the context analysis, it is possible to argue that educational institutions in Latin America have a lag with respect to technological advances and the changes that society itself. In this way, the virtualization of universities is a great opportunity to align this type of institutions with the current dynamics and trends around the world, since it allows expanding its range of action to places and media that were

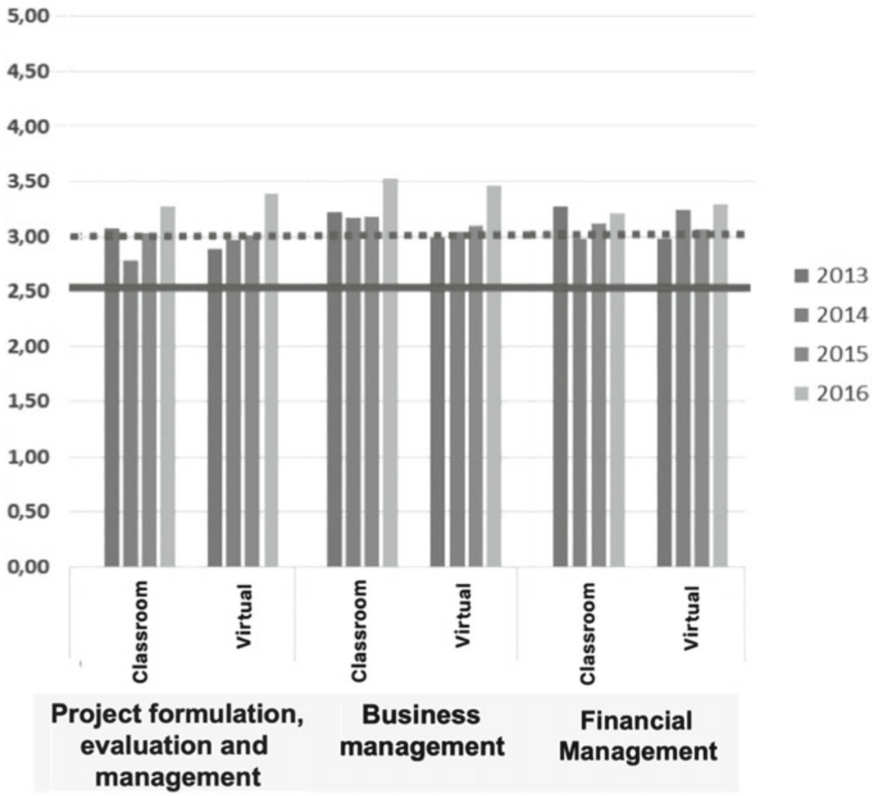

Fig. 3 Results of Saber-pro from 2013 to 2016 for virtual and classroom programs. *Source* Boada et al. (2018)

previously exclusive only to the classrooms, generating not only a greater coverage of the institutions but also generating inclusion and relevance of their actions.

Since 1996, the CEIPA Business School anticipated a significant change in which the education institutions needed to offer virtual programs that would allow reaching new students located in any region and that have special times for their education processes. In this way, the CEIPA education virtual model was born and was not conceived solely as a technology process, but required the development of its own pedagogical model that allowed the incursion of new technology into this new teaching methodology.

As a result of the combination of the pedagogical and virtual models developed by CEIPA, it was found that students and teachers are highly satisfied with the resources and materials available in the institution for the education process, which was evidenced in the self-evaluation surveys made by the institution. This result is strengthened by the analysis of the competencies acquired by CEIPA undergraduate students, which are evaluated through the Saber-pro tests, in which it was observed that it is not possible to establish a trend that indicates that virtual students are better or worse than classroom students. From this result, it can be seen that both virtual and classroom students have very similar results in terms of the acquisition of generic and specific competences, and in both cases, they exceed the values of the national average, demonstrating the success and quality of the virtual education model of CEIPA.

From the experience of the CEIPA case and the analysis of the Latin American high education context, it is clear that the academic institutions require a digital transformation that allow to respond to the new challenges and changes faced by the world, looking for closing the gaps between new necessities and old academic offers in the region.

As possible future works derived from this case study, this analysis can be complemented with information obtained from CEIPA graduated professionals who are currently holding positions in companies, with the aim of obtaining a more complete appreciation of their performance in the business environment. Furthermore, from this analysis, it is possible to determine new tools and information technologies that can strengthen the study programs, both at the undergraduate and at the postgraduate levels.

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Advances, Opportunities, and Challenges in the Digital Transformation of HEIs in Latin America

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Abstract The information society is characterized by the information data conversion and the information in knowledge to support the decision making and the human development. In this sense, the digital transformation implies not only the use of technology to store data, but also a change of processes and organizational culture, allowing the entry of knowledge management into the new economy of the intangibles. This transformation has changed the game rules of socio-technical systems of organizations and their interrelationships, impacting different components of organizations. Advance in adapting the transformation in organizations has not been symmetrical in all sectors and regions of the world. Previous research shows that in education in Latin America the degree of incorporation has been less than in other economic sectors and zones of the world. That is why, the objective of study is the identification and analysis of the progress achieved by the Higher Education Institutions (HEIs) of the region, concerning digital transformation of their academic and management processes, besides recognizing their opportunities and challenges in the context of the Fourth Industrial Revolution. The methodology includes a qualitative approach. To collect the information, the document analysis technique is used, and the main factor is the searching through reference database and complete text. Data analysis is made in accordance with the pillars of the Fourth Industrial Revolution, central and management, digital transformation enablers of missionary, and support processes of the HEIs. The results show that, while it is true that the HEIs in Latin America lag behind their peers in other countries, it is found that, from 2018, the progress on the digital transformation of processes of the HEIs in Latin America has been very significant. The main impact is given in the incorporation of pillars of industry 4.0 in: graduation, using blockchain; teaching, collaborative virtual reality;

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artificial intelligence to assist students; university management, through virtual assistants; and research supported by robotic. Improvement of cyber-physical and big data systems is not evident. It is concluded that digital transformation of the HEIs in Latin America is in the phase of early adoption, with some successful cases of the main reference HEIs, top-ranked in the academic ranking of the region, which will probably be imitated by other HEIs. The main challenges for the digital transformation of the HEIs in Latin America are related to culture, resistance to change, the hierarchical government, and the understanding that information is the key asset of the knowledge society. A new opportunity emerges for the digital transformation of HEIs in Latin America and for the researchers of the topic.

Keywords Digital transformation · Higher Education Institutions (HEIs) · Industry 4.0 · Latin American HEIs · Management in HEIs · Socio-technical system in HEIs

1 Introduction

The digital transformation (DT) is the organizational alignment between processes, people, and technology with the aim of complying efficiently with all the relevant activities of the company, to satisfy the needs and expectations of interested public around the Industry 4.0. The DT goes beyond the digitalization of process, and it is a deep transformation of the organization activities, processes, competences, and patterns to face challenges and take advantage of the emerging technology opportunities and its accelerated impact on society (Gobble, 2018). The DT includes people, processes, strategies, structures, and competitive dynamics (Wade, 2019).

The DT's scope comprises all sectors of society and therefore includes the Higher Education Institutions. In Latin America, there are 4.065 universities (Webometrics, 2020), and there is enough evidence of contributions they make to human, social and economic development of people and regions. For example, in the economical aspect, an exercise that modeled the impact of education in fifty countries between 1960 and 2000 found that one additional year of education could increase the income of a person in about 10% and the annual average gross domestic product (GDP) in about 0.37% (Hanushek, 2008).

The purpose of this research is to identify the progress, opportunities, and challenges in the digital transformation of the Higher Education Institutions (HEIs) in Latin America.

The document is organized as follows: preliminarily, the methodology, socio-technical system of the digital transformation, and the digital transformation in the management of the HEIs in Latin America; then, the management of universities in Latin America, the organizational structures, and the digital transformation in the HEIs; and finally, the digital transformation in the management of universities in Latin America and the technological dimension of digital transformation.

2 Methodology

This study applies a qualitative approach For the selection criteria of cases, it was considered that the HEIs were recognized or ranked in the first places of QS universities of Latin America. To access documents and relevant information, for the research, it mainly used the referential Scopus database, since it is one of the most recognized platforms of scientific information worldwide. The searching was done in English since it is the language in which most publications are found and with the aim of reducing bias. Following is the search equation:

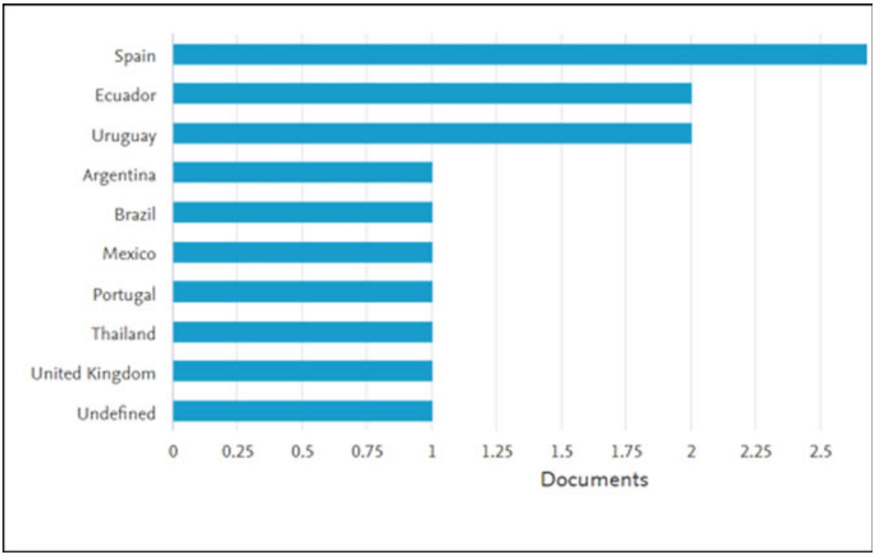
TITLE-ABS-KEY (digital AND transformation AND in AND Latin AND America AND universities).

Countries and universities that have done most of research in digital transformation are shown in Tables 1 and 2, respectively (DT = digital transformation and HEIs = Higher Education Institutions).

3 Socio-technical System of Digital Transformation

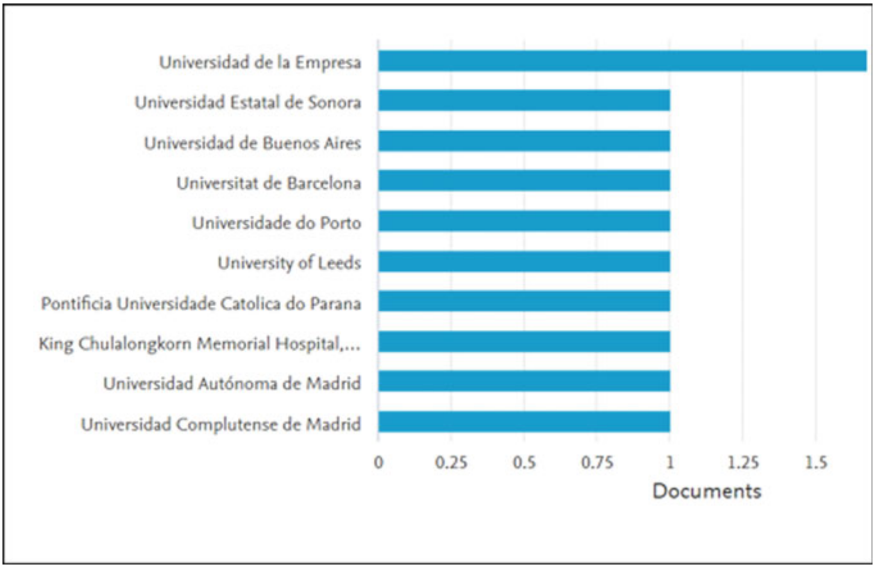
The university is a social artifact which is introducing digital innovations in the market, as well as in the academy and in research, and therefore, it drives the technological and social change with its implications. In this chapter, the relationship of the technical sub-system in interaction with the social sub-system is considered. The

Table 1 Research by countries



Source Scopus (2020)

Table 2 Relationship of HEI that have done most of the research on DT



Source Scopus (2020)

conceptual socio-technical pattern with the technical and social dimensions is found in mutual interaction.

> It is assumed that there are agreements between the parties involved for the achievement of their interests, which are represented in the different work structures and systems, necessary for the management of the organization, which are generally based on technological tools. Within the Organizational Technological System, the concepts of Core Technologies and Management Technologies are displaced, intended to serve as shock absorbers to prevent Core Technologies from being affected by contextual situations. (Díaz, 2020)

There is a reciprocal influence between the transformation and the organizational culture. From one side, it implies changes in the organizational structures that makes its culture to be impacted; in some cases, some people are empowered in the company; in other cases, they are disempowered due to the digital transformation. On the other hand, the organization's culture may cause that the resistance groups that emerge facing innovation, whether they are small or big, join the company in a normal or conflicting manner, because of the digital transformation.

3.1 The University as a Socio-technical System

The Tavistock Institute developed a research action project, related to the spreading of its work practices which produced an increase in productivity. This work was assigned the concept of "socio-technical approach" referring to the new paradigm of organizational work, by which it becomes necessary to find a new balance between requirements of the social and technical systems (Trist et al., 1963).

3.2 Organizations as Socio-technical Systems

According to the concept of a socio-technical system, organizations can be characterized from the existence of two large dimensions: the technical dimension whose rationality is the generation of products (goods and services) for the satisfaction of purposes for which universities were created, and the social dimension whose rationality is to ensure that interpersonal/social relationships are focused to satisfy an adequate interaction between people making part of the university and the requirements of the technical system.

The dynamics between the two sub-systems is complex, and it is considered of reciprocal influence: the technical system influencing the social system and vice versa. The technical system should impact the social system encouraging a change in the university culture and vice versa, but this is overly complex. This is due to multiple reasons such as: number of people participating as teachers and employees, and their high connection, by their interaction levels, by the kind of university decisions, or by the number of activities at the university.

3.2.1 Technical Sub-system: Core Technologies and Management Technologies

Thompson (1976) cited by Felcman and Blutman (2020) characterized the technical sub-system based on two types of technologies: core technologies and management technologies. Technology is the knowledge used by organizations to transform inputs into goods and services, to satisfy the purposes for which organizations were created. This knowledge can be “incorporated” in an artifact such as internet, a computer, etc., or also when it is “disincorporated”, when it is found in the patents, in the building blueprints, in the mind of those who have that knowledge (a teacher, a researcher or an executive from the university, etc.).

Also, technologies can be core technologies: those which are designed to meet the main objectives of the organization, such as educational technologies for teaching; the research and transfer of knowledge, or the TIC infrastructure; or management technologies: those designed to “isolate from context” or generation of “uncertainty” conditions for core technologies, as the university administration, communication, marketing, or the administration of the university campus.

Following this approach, complex organizations such as universities are social artifacts created on purpose to reach objectives that generate certainty within an uncertain context with which they interact. Under rational regulations, universities seek to “isolate” their core technologies from the context influences, protecting them with the provision of components of input/output to absorb the environment influences, leveling of transactions of input/output throughout anticipation of contextual changes, by planning and programming of activities, rationing when all of the above was not effective at the moment of protecting core technologies (Thompson, 1967).

3.2.2 Social Sub-system

For Felcman and Blutman (2020), in the social sub-system, while there are several concepts that can be highlighted as components, emphasis is made in one which is considered the base of the others: the organizational culture and the university culture. Organizational culture is defined as a "pattern of made basic assumptions, discovered or developed by a group focused on learning how to face their problems of external adaptation and internal integration, who have had enough influence as to be considered valid and, as consequence, be taught to new members as the correct way to perceive, think and feel those problems" (Schein, 1988).

Schein identifies and distinguishes three levels of the organizational culture: A visible level is composed of artifacts as objects, written standards, rituals, symbols, and the labor environment; a second level is composed of values, which are the preferences that members of an organization have, with respect to certain organizational issues over others (remunerations, social benefits, spare time, interaction with other members of the organization, satisfaction with tasks being performed, compromise, self-realization, progress); the basic assumptions are the deepest and "invisible" beliefs that make up the "organizational collective unconscious."

3.3 Internet as a Social and Technological System

When speaking about the knowledge society, we speak about a socio-technical transformation, since all societies are of "knowledge." In this case, it is about a society in which the conditions to generate knowledge and information processing have been considerably altered by a technological revolution, focused on information processing, to the generation of knowledge through the information technologies (Castells, 2003).

Internet is a cultural creation that allows the emergence of a new economy and the development of innovation and economical productivity. But Internet is revealed as a culture through a social practice that conceives cultural diffusion, a dimension referring to a visible level composed of devices, a value level, and a belief and way level to mentally constitute the university community, which is decisive in the generation of ways of these technologies and which is a key factor paradigm. The fact that Internet is a culture that allows the creation of new conditions for organization and innovation, as a support of the new economy, reorganized in networks and innovated regarding capabilities of new ways to create added value, is only possible thanks to the network technology. Those universities use Internet to organize their network operation from the innovation of new digital technologies (Castells, 2003).

3.4 Governance of the Socio-technical Model

The corporate government identifies the strategic actors who get involved in the university processes, for the university to comply with its purposes, through theories such as the agency, the company, and management of knowledge.

It is considered that the university is an economic entity whose purpose is to maximize the economic profits through costs of its transactions. The university management implies some costs which are not absorbed by prices, such as: the cost of search for students and teachers, cost for differentiation of tuition costs, cost of contract negotiation to carry out its transactions, and the cost to guarantee that what is agreed in the programs is fulfilled, as well as costs to devise the different programs; these are commonly called transaction costs.

However, there is still another theory defined with respect to cost saving for coordination of the teacher training in the university, which establishes the duration and restrictions of such costs that is determined by teacher incentives. Therefore, the promoting of low-powered incentives in the university is as well an important factor to inspire cooperation and coordination (Díaz, 2020).

On the other hand, power delegation/responsibilities should be considered, between an agent and executive (dean, academic vice-rector, etc.) for the teacher to do on his behalf teaching activities through the contract theory.

Finally, for Tarziján (2003), cited by Díaz (2020) to operate efficiently, the university needs specific physical assets as well as human resources (they constitute an intellectual capital stock), which generates what is called the theory of the firm, based on knowledge (technology). These are investments in human resources, language, particular routines of the university, tacit and explicit knowledge, common ideas, etc.

> Governance is how the groups are organized in the university to make or implement decisions in common agreement between the members that make up the corporate government, to accomplish their objectives, to arbitrate their discrepancies and exercise their rights and legal obligations, to comply with the university goals. This is what determines the north of the university, through the system of strategies, policies, values, regulations, practices, mechanisms, and processes that set up the restrictions for the administration of its economic, political and social issues inside and outside of it. Also, there are two essential elements: The Government Codes which are the adopted methods (tacit and explicit), to specify the governance processes, and the Governance Tools which are the instructions or instruments that operate the methods and define the options to implement them out (Díaz, 2020).

Going back to the socio-technical model, the purpose of the social sub-system is to ensure that interpersonal/social relationships are aimed at the adequate interaction between people that are part of the organization and the requirements of the technical system. In this sense, coherence is the logical relationship between the two parties or realities, so that no contradiction nor opposition is generated between them and keeps them in the same position.

In other words, in the universities, due to the consolidation between the administrative patterns, the type of governance is created, the type of culture that has been generating a coherence. This coherence has been around for years because, between the administrative model, governance, technology, and the university culture, such coherence was present.

With the advent of the new digital technologies, the rupture of coherence has occurred. This happens when the logical relationship between realities is broken, which produces contradiction. The university has been managed according to a technological structure and the vision of conceived university since its beginning. With the arrival of the Fourth Industrial Revolution, as it was expected, the university vision changed, and consequently decisions are to be made according to the organizational culture and corporate government. It is expected that this causes the coherence rupture.

From the university culture, it is expected that the university promotes the development of the soft skills, which tend to disappear with the technology massification. From the corporate government, training must be formalized in the new digital technologies, as well as in core and management technologies.

4 Management of Latin American Universities

Management in Latin American universities, since nineteenth century, is originated and supported by several administrative theories which make emphasis on the basic functions that integrate the management process, the labor division, the definition of authority levels, the discipline, the control unit, the subordination unit, the remuneration, centralization, hierarchy, order, equity, personnel stability, initiative, binding results; all this originates the concept of administrative process and departmentalization, and ends up in the achievement of the organization results.

Díaz (2020) synthesizes the administrative theories as well as their evolution through corresponding patterns. Table 3 shows how those patterns are reflected at that moment.

Table 3 Organizational theories

Theories and organizational patterns	
Theory of scientific administration • Organizational pattern of continuous improvement (Uran, 1961; Crosby, 1979)	Human resources theory • Organizational pattern (Adhocratic & Mintzberg, 1979)
Theory of bureaucracy • Pattern of bureaucratic organization (Max Weber, 1922)	Classic theory of administration • Organizational pattern of competitiveness (Porter, 1990)

Source Díaz (2020)

Administrative management is the process by which the organization schedules, plans, organizes, leads, controls, and evaluates the results; all this depends on each organizational pattern (model).

Organizational patterns, from these theories, are classified as hierarchical, adhocratic, clan, or market type, while their structures can be matrix, by processes, or in networks. They can be high or flat, depending on the decision and control levels defined by the institution.

5 Organizational Structures of Universities in Latin America

Rodriguez-Moscoso (2020) states that Latin America started a specific pattern of university, from the Córdoba Reform of 1918, characterized by the autonomy of its institutions, with a management framework based on the modality of co-government. The dominant pattern in Latin America is basically similar to the Napoleonic pattern. The autonomy, co-government at the institution with the participation of students, teachers, graduated with voice and vote in the governing bodies make of this a democratic and participative pattern.

However, the university government is hierarchical, Pyramidal, and departmentalized, with authority levels and control clearly defined in statutory rules. Autonomy is clearly a characteristic of the public and private university management in Latin America. It keeps a structure of hierarchical organization by substantial functions of the university and a structure by processes of the support areas. Organizational structures of Latin America are matrix structures. The organizational pyramid, for the university management, is implicitly aligned with the institutional pedagogical pattern, which leads to the functional missions and to the support processes, with reliable and timely information for decision making that ensures the achievement of the university goals.

The Government of Latin American universities has not changed significantly, and it remains hierarchical, in both public and private universities. What has changed is the way of generating impact in remote regions. In the case of teaching and learning activities for distant populations from the headquarters, previously education was developed through the radio, execution of physical guides, self-training validated by the state, or regional distant education centers—RDEC.

Today, although the distance modality still persists, the academic activities developed through the virtual modality have increased exponentially. In this modality, the pedagogical models supported by the use and appropriation of ICTs have made it possible to bring knowledge, virtual classrooms, and self-managed development to remote places where students are. Therefore, the methods and means of reaching distant places have evolved: first, self-learning; then radio and television; and later, with the appearance of the Internet as a hyper-transformer and inducer of a fundamental change, the classroom was brought to the student.

In the virtual mode, on the one hand, the administrative activities required to support academic activities are generally carried out centrally. On the other hand, academic activities can be developed in a centralized or decentralized manner depending on the policies of the IES. Centralization is reflected, for example, in the hiring of teaching staff from the headquarters to teach academic activities in the virtual mode, regardless of the geographical location of the students. Decentralization occurs when both students and teachers are relocated far away the headquarters of the HEIs.

6 The Digital Transformation in the Management of University Institutions of Latin America

Digital transformation is understood as the process by which a Higher Education Institution breaks the management paradigms of the past and reinvent them through a creative disruption, supported by the utilization of digital technology, with the aim of achieving a more effective management, generating relational capital with its reference groups, and the institutional positioning. That is why the digital transformation is not only the use of technology to store data, but above all, a change in the existent organizational culture, to allow and facilitate the entry into knowledge management, in the economy of its intangibles.

The political decision of the world countries to open their frontiers removed the geographic barrier. Technology and communications evolved and wired together, which at the end produced digitalization, leaving a global world with no frontiers, without barriers, with communication accessible to all, and becoming a right of all humanity.

This reality is described by McLujan (1962, 1994) when he says that in the beginning there were no communication means as we know them today, nor the way they were at the end of twentieth century. For Fridman (2005), the globalization forces have emerged in economic, commercial, and political structures, changing from being rigidly vertical to be frankly horizontal; that is how the world is flattening, leading to a new era of collaboration between individuals and communities as never seen before, which is affecting the way of doing business, as well as the role governments play.

For Guajardo (2020), the digital transformation, in the Latin American universities, is not only a solution to common challenges of universities, but also a change of mentality that creates more efficient processes in the management and pedagogical experience.

6.1 Management of the Higher Education Institutions in the Digital Transformation

Guajardo's research (2020) clearly shows the digital retardation of universities, where it is evident that only one-third of them become digital explorers. The Enterprise Resource Management (ERP) emerges as a response to a culture of silos management, in which, for each process of the organization, it was used an information system, generating problems of redundancy and integrity of information. The ERP is the response to that tendency of development of information systems defined as "silos," in which every problem of the organization was solved through an isolated information system, generating redundancy and lack of integrity in the information. Until the beginning of the twentieth century, the information was obtained and processed manually. Digitalization arrived with functional solutions, for a university management supported not only on data and reliable and timely facts, but also on analysis, interpretation, and applications for the decision making that generate new knowledge.

6.2 Impact Areas of Digital Transformation

Emerging digital technologies can have an important impact on the digital transformation of universities in Latin America. Duparc (2013) states that the real digital transformation is achieved when all the organization assumes the importance of the digital culture and makes it her own at all levels. Besides this, he says that it is not a technology problem but a people and structure problem, and he confirms that the real digital transformation is achieved when all the organization assumes the importance of a digital culture making of it her own culture at all organizational levels, adopting a new model of management that must be incorporated systematically throughout the following components:

6.2.1 Sustainability of the University Campus

It is necessary to incorporate technology to support the institutional policy about care and conservation of environment.

6.2.2 Infrastructure of the Communications and Information Technology (CIT)

Emerging technologies may have an important impact on traditional technological infrastructures of universities.

6.2.3 Infrastructure for Information Processing

The digital transformation has implications in the data processing centers of universities.

6.2.4 Communications Infrastructure

The digital transformation has influence in digital technology development in the telecommunication structures of universities.

6.2.5 Administration

The Higher Education Institutions are complex organizations, and as such, they need to manage the information. Digital transformation supposes a new "turn of the screw" on using CIT for the administration of universities.

6.2.6 Processes of University Management

It is necessary to analyze the impact of emerging digital technologies in the process automation of university management, with a future vision in the knowledge and the emergence of the economy of intangibles.

7 The Technological Dimension in the Digital Transformation of the Higher Education Institutions in Latin America

The technological dimension of digital transformation is made up of data, software, hardware, and communication networks. Data processed and converted into information are the source of knowledge for decision making in the organizations (Loshin, 2012); therefore, they represent an input for the information to become a key asset of companies, and they are essential for the analysis, diagnosis, and the generation of early warnings in the organizations.

Regarding software, hardware, and communication networks, there are several types of tools and information systems that allow the incorporation of digital transformation, in the business processes of organizations. Among the main types of tools are ERP—Enterprise Resource Management, CRM—Customer Relationship Management, SCM—Supply Chain Management, ERM—Enterprise Risk Management, and KM—Knowledge Management, among others. Nevertheless, at the moment, the digital transformation is mainly supported by technologies of the Fourth Industrial

Revolution. That is why, in this abstract progress on digital transformation is analyzed regarding the Higher Education Institutions in Latin America, from the main pillars of the Industry 4.0, whose fundamental concepts are presented below.

7.1 The Technological Pillars of Digital Transformation

Industrial revolutions are understood as disruptive changes affecting all sectors of society (Schwab, 2016). According to Schwab (2016), along the history, four industrial revolutions are recognized: The first one took place on the eighteenth century, and it was characterized by passing from manual production to mechanized production; the second one was originated on the nineteenth century, and its main characteristic was the generation and use of electric power; the third one arose with the electronic computer on the middle of twentieth century; the Fourth Industrial Revolution arose on 2011 in Hannover, Germany, and it was strengthened on 2016 at the World Economic Forum—WEF—from where it has been promoted. The main characteristics of the Fourth Industrial Revolution are the cyber-physical systems, which consist of the imbrication of physical and digital processes.

Incorporation of innovations in the companies, from the Fourth Industrial Revolution onward, depends, in great measure, on pillars: artificial intelligence, Internet of things, cloud computing, business intelligence, big data.

Artificial intelligence is referred to intelligent behavior in artifacts (Nilsson, 1998).

Internet of things is the relationship between the things—products, services, places, etc., and people and processes made possible through technologies connected by different platforms (Schwab, 2016).

Cloud computing is external provision of technology information (TI) services of the business accessed via Internet, Massachusetts Institute of Technology (MIT, 2012).

Business Intelligence means the conversion of data in information and information in knowledge for decision making in the organizations (Loshin, 2012).

Big data is the management of large information packages characterized by volume, variety, and speed (González et al., 2013).

Cybersecurity, meanwhile, is about ensuring confidentiality, integrity, and availability of the information in the cyberspace (Sutton, 2017).

The pillars of the Fourth Industrial Revolution support the efficiency of the value chain of organizations. In this sense, they may be considered, according to Thompson's classification, as being core technologies as well as management technologies or both. The tendency is for technologies to respond and behave in accordance with the business processes; the core and support processes of companies are interconnected through the information, and the valuable activities, likewise, technologies tend to be less specialized, and on the contrary, they support as many processes as possible of organizations.

7.2 The Digital Transformation in the Higher Education Institutions of the World

The first four economic sector leaders in adopting the pillars of the Fourth Industrial Revolution are in order as follows: telecommunications, insurance, advertising, and financial services (STATISTA, 2019). As observed, education is not among them; nevertheless, we cannot deny the importance that this represents for the development of regions and people, and the worldwide progress in this sense. The 4.0 education is a phenomenon that changes the rules of the game in the education sector, placing the student at the center of the ecosystem, and changing the teaching focus to learning (FICCI, 2018), it goes from massive learning to personalized learning, according to characteristics of students and not independent from them as it was before. Some of the main cases have occurred in Higher Education Institutions of the USA, Australia, and Japan.

In the USA, it is relevant in the case of the State of Georgia University, which uses data analytical and predictive systems with more than 800 pre-established alerts to track the students' behavior on a daily basis, and so have an early detection of possible dropouts (Georgia State University, 2019). During the last 10 years, the main impacts of the project are as follows: increase of the number of graduations in about 22%, USD 15 million savings in tuition payments, comparing year 2016 with year 2012 (FICCI, 2018).

In Australia, the case of Deakin University is important, and they use artificial intelligence and machine learning through the Watson IBM tool to help the students find easy and quick information. The tool is called "Deakin Genie," and it provides answers to the students about the following topics: admissions, course registration, financial aid, student residences, skills evaluation for work and extracurricular activities, among others (FICCI, 2018).

In Japan, the University of Hong Kong implemented an inter-institutional collaborative project called "Connect Ed Program." The main purpose of the project is, through a cloud platform, to facilitate the ideas and information interchange between the students at the university, in England and other countries on topics related to the health area (FICCI, 2018).

7.3 Preparing of Countries in Latin America for the Industry 4.0

On 2018, the World Economic Forum (WEF) produced the first version of the competitiveness index 4.0, which is made up of a series of new emerging factors that determine productivity in the period of the Fourth Industrial Revolution (WEF, 2018; FEM, 2018). In accordance with the WEF, the index, whose qualification goes from 0 to 100, has 98 indicators organized in 12 categories: institutions, infrastructure, adoption of information and communication technologies, macroeconomic stability, health, people skills, product marketing, labor market, financial system, market size, business dynamism, and innovation capacity.

All categories are important; however, the one directly related to the technological dimension of digital transformation, using the pillars of the Fourth Industrial Revolution, is the adoption of information and communication technologies. The factor is made up of 4 indicators: cell phone subscriptions, mobile broadband Internet subscriptions, fixed broadband Internet subscriptions, optical fiber Internet subscriptions, number of users in Internet (WEF, 2018; FEM, 2018). In the 2018 version, 7 regions of the world and 140 countries were compared.

Regarding world regions, the first 5 places in the global index of competitiveness 4.0 are: USA with 85.6 points, Singapore with 83.5, Germany with 82.8, Switzerland with 82.6, and Japan with 82.5. The average of North America and Europe is 70 points, the average for Eastern Asia and the Pacific is 69 points, while for Latin America is 56 points. As it can be seen, there is a huge gap between Latin America and the leader countries in the required conditions to adopt technologies in the Industry 4.0.

Regarding the comparison between the Latin American countries, the first places in the ranking are for Chile, Mexico, and Uruguay, with 33, 46, and 54 points, respectively. Then, next places are for Costa Rica, Colombia, Perú, and Panamá with 55, 60, 63, and 64 points, respectively. Then appears, Brazil, Dominican Republic, Ecuador, Paraguay, Guatemala, El Salvador, Honduras, Nicaragua, Bolivia, Venezuela, and Haiti. These two last countries are in places 127 and 138, respectively, out of the total of 140 countries. Just as there are gaps between the regions of the world and Latin America, there are also gaps in the interior of the regions to comply with the conditions for the implementation of the 4.0 technologies.

7.4 The Digital Transformation in the Higher Education Institutions of Latin America

There is evidence of progress in the incorporation of pillars of the Industry 4.0, for the digital transformation of academic and support processes of the Higher Education Institutions. For the analysis, out of those institutions were taken into account those ranked in the first 10 places of the QS Ranking Latin America according to its most recent version (QS, 2020). Therefore, for the study cases, universities from Chile, Brazil, Mexico, Colombia, and Argentina were considered.

In Mexico, the "Tecnológico de Monterrey", in 2018, for the first time did a class using collaborative virtual reality between students from several university campus, in an experience 100% of virtual immersion (Tecnológico de Monterrey, 2018). The class has the same academic credit value as a face-to-face class. Likewise, since 2006, the "Universidad Nacional Autónoma de México" (UNAM) designed the Robot Justina, which on 2019 ranked the second place during the worldwide innovation event RoboCup 2019; the robot is used for research (UNAM, 2019). In addition, "Universidad Insurgentes" is a success case in the use of business intelligence for higher education; the strategy was supported on ERP (Ellucian, 2020).

In Colombia, the case of "Universidad del Norte" of Barranquilla is relevant, which uses artificial intelligence to advise students, through the Robot Steve. According to the university, the students can query Steve (the robot), about administration and business topics, initially in English, and the machine learns based on the previous questions and answers presented (Universidad del Norte, 2019). In the same way, the "Universidad de los Andes", in 2019, bought from the Japanese company Softbank the robot they called Opera. The robot, similar as the one from "Universidad Nacional Autónoma de México" (UNAM), participated in RoboCup 2019 and it is at the present time being used for research. According to the university, the robot is being programmed to support and guide the students in the induction processes and guide the students to any place in the university (Andes, 2019).

In Argentina, the "Universidad Provincial del Sudoeste de la Provincia de Buenos Aires (UPSO)," in 2018, became the first public university in Argentina to use blockchain to guarantee authenticity of diplomas of its regular and continuing education programs (UPSO, 2018).

8 Accelerators of Digital Transformation

The digital accelerators are environmental, cultural, and behavioral aspects of the digital economy, which favor digital activities or initiatives (Accenture, 2020). Governments and ironically the current COVID-19 are among them.

Regarding governments, if the first Latin American countries in the competitiveness 4.0 index are observed, they are countries where there are stated policies through development plans, CONPES, decrees, or laws that create conditions for the digital transformation to become a reality in those countries, such as in the case of the first five ranked countries: Chile, Mexico, Uruguay, Costa Rica, and Colombia.

About Chile, the development national plan 2018–2022 includes among its strategic objectives the strengthening of the digital infrastructure of the country, facing the challenges of the technological revolution (Observatorio Regional de Planificación para el Desarrollo, 2020). Regarding Mexico, the Development National Plan of Mexico 2019–2024, although it is not explicit about digital transformation strategies, it does state an interest to massify the Internet coverage for the whole country (ILPES, 2020). Regarding Uruguay, in its development national strategy Uruguay 2050, it considers the guideline to take advantage of the opportunities of digital economy, strategy which seeks to "make of Uruguay a model of the new digital economy, promoting the Technology, Information and Communications (TIC) not only as a productive complex in itself, but also as an innovation vector acting as a support and a development engine for all sectors" (CEPAL, 2020, Section guideline 2).

In the Costa Rican case, one of its objectives is "to promote the digital transformation of the country through the development and evolution of international mobile telecommunication system (IMT), to enable the generation of innovating services, and promote competitiveness" (United Nations, 2020, Innovation Section, competitiveness, and productivity). In the case of Colombia, its National Development Plan 2018–2020 includes the agreement for the digital transformation in Colombia and states that government, business, universities, and households will be connected with the Age of Knowledge, and that "we will encourage a state policy for the digital transformation and to benefit from the fourth industrial revolution" (DNP, COLOMBIA, 2020, p. 132). The international mission of Experts 2019 proposed a strategy about financing the information technology (to improve the educational model and the regional development based on the generation and use of knowledge (Presidencia de la República de Colombia, 2019). In the same way, in Colombia, the National Economic and Social Policy Council of the Republic of Colombia—CONPES, 2021–2030, indicates that it is necessary to adapt the environment for the adoption of Industry 4.0 technologies.

As it is seen, in countries where governments show real interest in promoting the digital transformation, the progress is considerable. It is all the opposite to see what happens in other countries of the region such as Cuba, Venezuela, and Bolivia, where lags are evident and where there is no evidence of massification and appropriation of the technology information and communications, at least the way done by countries that in this sense are ranked in the first places.

Besides governments, other circumstances that have driven the digital transformation are ironically the current pandemic COVID-19 that has considerably accelerated a wide range of digital processes, not only in Colombia but in the rest of the world. Quarantines and other mobility restrictions triggered the use of digital solutions, for the most diverse activities of daily life. The scourge persists. Although the present crisis did not generate the necessary digital transformations in all sectors, the struggle measures against the new coronavirus, worked out as a catalyst of technologies, habits, costumes, and consumption.

The Organisation for Economic Co-operation and Development (OECD) published its Index of Digital Government (IDG) for this year, and Colombia ranked the third place, behind South Korea and the UK. This scale measures the grade of "maturity" of digital policies in the governments of the different OECD country members, which include several of the richest countries of the world. The remarkable performance of the country reflects the compromise of the national government, with an agenda of digital transformation, led by the tightest circle of the Nariño House. The above facts do not mean that the task in this front is accomplished. It is all the opposite, and it confirms that the more advanced countries in digital transformation count with the frames of public policies, the institutional actors, the private sector, and the vision to go on.

9 Discussion and Conclusion

The master study in which progress has been presented, in the digital transformation of the HEIs, in Latin America, focused on making more efficient their mission and management processes, and it is found that, from year 2018 on, the incorporation of pillars of the Fourth Industrial Revolution has been intensified. Applications are found to support management, as the blockchain case, for the issuance of diplomas and the virtual assistants to give responses to general inquiries from interested public. In the same sense is found the application of artificial intelligence, to support research processes, give responses, and solve doubts of the students on specific topics of certain subjects. This progress is causing the modification of the business models of the HEIs. Nevertheless, more than digital transformation, what we find now is the digitalization of processes, cultural change is still needed. The main barrier for the digital transformation in HEIs is the culture, in the same way as previous studies have shown, it also happens in the education sector of other regions as Europe, where it is found that the main restriction is the insufficient technological resources and the conservative culture (Vicente et al., 2020).

Regarding resource availability, the main income source of most of the HEIs of Latin America is the tuition payments from students, with a participation of more than 90% in the private HEIs. In public HEI, financing depends on the government with limited resources; this explains why more relevant progress comes from HEI of recognized quality but also because of their resources. Therefore, although they present progress, there are investment restrictions in technology information and communications (TIC). Regarding cultural issues, the HEIs of Latin America have the same conservative culture of the world's HEI. The economic aspects can be solved easily, but not likewise the aspects concerning culture.

Therefore, the main challenges of the HEI of Latin America, for the incorporation of the digital transformation, are the management of the organizational cultural change of the HEI sector, the progress in the same proportion of the social and technical systems, together with the gradual change of style of hierarchical government, departmentalized and pyramidal, to a more horizontal one, in which government and governance coexist. Governments play an important role as accelerators of digital transformation.

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Digital Transformation of Academic Management: All the Tigers Come at Night

Marcel Simonette, Mario Magalhães, and Edison Spina

Abstract Latin America higher education institutions have been participating in several academic networks promoted by European Commission. There are cooperation, mobility, and research programs to help and support institutions development. However, the Fourth Industrial Revolution brings a disruptive scenario, challenging these institutions to go beyond academic cooperation and undergo a digital transformation, offering answers to this new revolution that is changing the world in never-before-seen form and speed. Tools and approaches originated in the business sector may help higher education institutions to promote their digital transformation. Nevertheless, these institutions have characteristics that differentiate them from the traditional managerial business. Moreover, these characteristics are a source of tensions, night tigers that are adversaries but invisible on a day-to-day transformation activity, impacting the digital transformation process. This chapter presents the double triad model: "rethink the business" and "rethink where is the business" to create an integrative framework, a strategic playing field to understand, manage, and overcome the challenge of dealing with adverse digital transformation scenarios.

Keywords Academic management · Strategic planning · Sociotechnical systems

1 Introduction

Since the First Industrial Revolution, technology has shaped our society, demanding new professionals and changing work nature. The current Fourth Industrial Revolution is not different. It gives rise to Industry 4.0, marked by intelligent environments

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in which humans and cyber-physical systems interact, exploring distributed resources such as cloud computing. It is a profound transformation in operation patterns, driven by a new human–machine interaction supported by artificial intelligence (AI).

The change promoted by AI in the way of work impacts the society and the academy. Frey et al. (2016) estimate that 47% of the US jobs—and a higher percentage in developing countries—will be at risk. Higher education institutions (HEIs) have been working in new courses, disciplines, and curriculum to prepare people for the unique demands of Industry 4.0. However, AI progress goes beyond the changes in the way of work; it impacts the economic mechanisms and business models directly (Loebbecke & Picot, 2015).

HEIs have a permanent relationship with society, impacting and being influenced by social and industrial environments. In the twenty-first century, they need to expand their focus, going beyond educating and tutoring students. HEIs need to generate strategies that match the institutions' skills and resources to the opportunities and associated risks in their environment. They must be attractive to the students, considering the market appeal without losing the rigour of the courses, programs, and academic autonomy. However, the challenges confronting academic management make it difficult for HEIs managers to allocate sufficient time and focus on substantive strategic thinking and planning without a radical solution.

Latin America higher education institutions have accumulated a significant potential, developed through an evolutionary path of several educational and cooperative networks promoted by the European Commission. The experience and knowledge resulting from this cooperation can be an essential management resource in Latin America higher education's strategic management system (eMundus Project, n.d.; Riccardi et al., 2012).

Through this path, it has been perceived that tools and approaches that originated in the business sector may help HEIs in the search for a solution. However, these approaches need to be adjusted to the higher education context and needs. The key relevant characteristic that differentiates HEIs from the traditional managerial business models is professional autonomy, a source of tension between top managers and academic professionals (Baldridge, 1971; Birnbaum, 2000; Meyer Junior et al., 2018).

HEIs face a disruptive scenario. It is necessary to transform their business to go beyond the integration into the local, regional, and global educational environments without losing individuality and autonomy. HEIs need to use technology and data to evolve, actively linking their stakeholders, increasing their commitment, and strengthening their experience to consider:

- the market attractiveness,
- the academic rigours of the courses and programs, and
- academic and research autonomy.

Several HEIs are adopting digital strategies in reaction to the scenarios imposed by Industry 4.0. However, although these strategies use new technology and data, there is a lack of vision, capability, or commitment to effectively implement them (Fleming, 2018; The 2018 Digital, 2018). In this sense, it is relevant to construct a comprehensive vision of digital strategies to develop the digital transformation of HEIs (Benavides et al., 2020).

This chapter explores the elements that are essential to the planning and implementation of digital transformation on HEIs. This exploration deals with HEIs distinctive characteristics as internal and external dimensions, purpose, structure operations, business model, society, and stakeholders. It is a socio-technical construction of the planning of HEIs digital transformation with a social constructionism approach. It is organised as follows: In Sect. 2, we present the digital transformation concepts we adopted, especially its triads; Sect. 3 is about digital transformation in the HEI environment. In Sect. 4, we characterise the risks; the tigers present in the transformation process need to be considered and treated for the endeavour's success, which is discussed in Sect. 5. Section 6 brings the conclusion; the references follow it.

2 Digital Transformation

Digital transformation uses technological resources, mainly related to data digitalisation, storage, search, and communication, to rethink the business and where the business is positioned.

2.1 Triads

Although the research on triads originated in sociology (e.g., Caplow, 1956), management and business researchers developed several triads studies. Havila et al. (2004), Madhavan et al. (2004), Phillips et al. (1998), and Ritter (2000) are some examples. Smith and Laage-Hellman (1992) and Ritter (2000) argue that analysing triads in networks is sufficient to understand network elements' interrelations. Furthermore, triads allow the generalisation from the micro to a broader network level (Easton & Lundgren, 1992). Consequently, a triad is the tiniest unit that supports the simplification of inter-organisational network analysis.

A relevant characteristic of a triad is that it is never stable. There is no perfect balance between all the three dyads that compound the trio (Carson et al., 1997; Gutek et al., 2002).

2.2 Digital Transformation Triads

There are internal and external relations in all businesses. Power struggles and influences need to be analysed to explore the depth of the digital transformation impact.

2.2.1 Rethink the Business

Internally, the business digital transformation only occurs when the triad established by business purpose, structure, and operation (Fig. 1) is profoundly affected in the process. The transformation result is a new business that may or may not have technology as one of its essential parts.

Digital transformation affects and redefines business. Moreover, it affects both individuals and society, individuals, in their daily activities and how these activities are perceived, and society, in the understanding and valuing of the business and its regulation concerning how it is carried out traditionally.

An example of digital transformation—and its impact on individuals and society—is the personal transport business rethought in its purpose by Uber. The business purpose changes from private transportation to personal vehicle-sharing business, valuing a minimalistic operation and less concern with traditional structures of people, associations and government. An operation dependent on digital resources for easy access, communication, and information storage. In general, individuals perceived this transformation as positive, but it is not necessarily perceived as positive for society. The term "society" considers all forms of associations relevant to the business, for instance: tax structures, legal basis, government procedures, drivers' associations, taxi, and transport companies.

Changes are inherent to business, which contribute to business triad's instability (Holma, 2009). Changes in any of the three forces of the triad represented in Fig. 1 transform the business. More or less intensely, the results of the changes will hang towards two of the three vertices of the triangle that represents it (Fig. 2):

- The prevalence of purpose and structure drives an operation that can be cumbersome, affecting operational profitability (**bureaucrat vision of the business**).
- The prevalence of structure and operation jeopardises the understanding and realisation of the business purpose (**pragmatic vision of the business**).
- The prevalence of operation and purpose can lead to disconnected or inefficient structures that can hinder business growth (**liberal vision of the business**).

Any business visions (bureaucrat, pragmatic, or liberal) result from the business triad's instability. The digital transformation in organisations does not improve at the

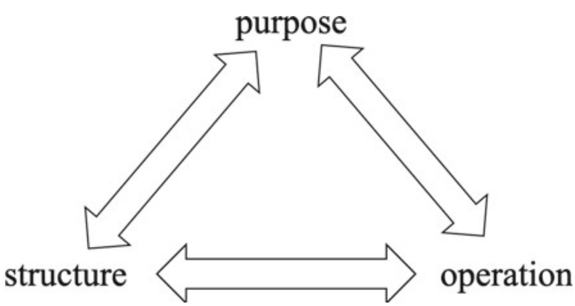

Fig. 1 Business internal relations. The internal business triad forces: purpose, structure, and operation

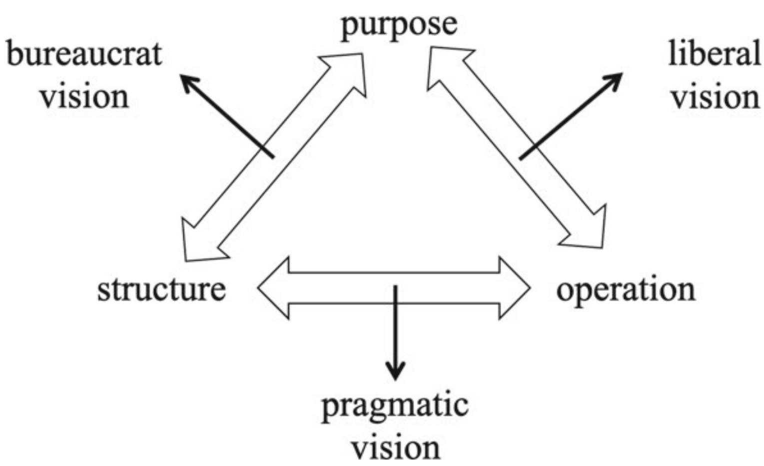

Fig. 2 Business internal relations. The business triad forces purpose, structure, and operation with the resultants stabilising business visions ("rethink the business")

same time the business and equally their purpose, structure, and operation. However, the prevalence of dyads is not a problem for business success and acceptance. It is necessary to align the business vision with the rethinking of where the business is, or where the institutions or organisations want to reposition or focus the business and resulting potential conflicts.

2.2.2 Rethinking Where is the Business

In a vision external to the business, the triad determined by the business, individual, and society (Fig. 3) determines the business transactions' success and acceptance. As usual for triads, there is no stable solution that meets the three forces:

- The prevalence of the business and the individual is a situation in which there is a lesser interference of the organised society or government on individual rights and business regulation. There is the possibility of abuse of the business's power over the individual (**unbalanced transactions view**).
- The prevalence of the business and organised society results in restrictions and limitations of individual options or collusion cases (**unfree transactions view**).
- The prevalence of organised society and the individual over the business can create situations that make the new and innovation unfeasible, reinforcing the maintenance of comfortable but inefficient and static solutions (**non-innovative transactions view**).

The business internal relations triad (Fig. 2) and the external business visions triads (Fig. 3) are powers and influences that need to be analysed to explore the depth of the impact of digital transformation. These two triads are as Yin and Yang; a

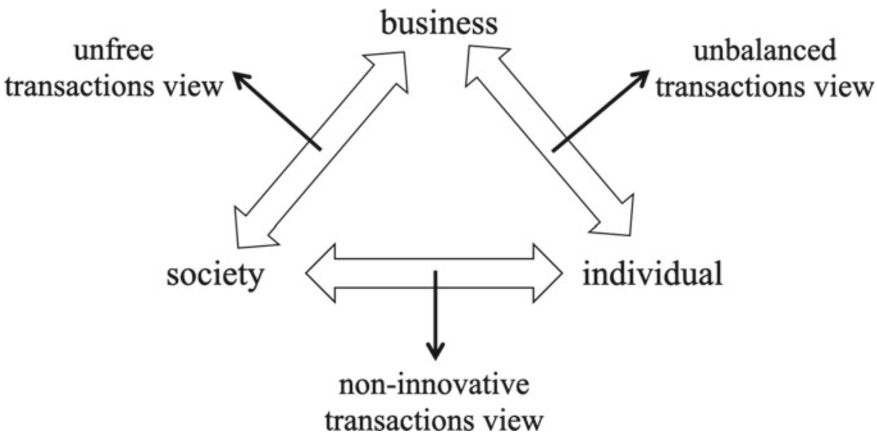

Fig. 3 External business visions triad: business, individual, and society. The resultants of triad instability establish how the business and its transactions are perceived by individual and society, which may determine the business's success and acceptance ("rethink where is the business")

kind of dualism, powers and influence that are complementary, interconnected, and interdependent (Yin and Yang, n.d.).

3 Digital Transformation in the HEI

What can or should be done to explore the depth of the impact of digital transformation in HEIs? The success and acceptance of the HEIs in the Fourth Industrial Revolution as a social-technical problem go beyond traditional project scope and relations.

3.1 Beyond Students—Teachers Relations

Digital transformation in the HEIs is holistic. It is a transformation that changes higher education and changes academic culture, impacting individuals and society. Benavides et al. (2020) conducted systematic literary research about digital transformation in HEIs, identifying that digital transformation changes HEIs formative activities and evaluations, the institutions' administration, research, extension processes, and individuals and society.

The mere adoption of technology to support educational processes, and to formulate simple administrative processes to meet the market demands or buzzwords, does not promote the necessary transformation of HEIs business model to deal with the Fourth Industrial Revolution's challenges.

Considering the HEI business internal triad, operation and structure are deeply changed by technological resources—mainly related to data digitalisation, storage, search, and communication—and are the basis for rethinking business. These resources allow the improvement, enhancement, or replacement of the HEIs business processes to promote the institution's transition to a new way of thinking their business, simplifying the processes of education and research services (Gafurov et al., 2020; Tay & Low, 2017; Thoring et al., 2018). Moreover, these resources allow a new kind of academic–society–industry relationship, although HEIs main purpose should be preserved.

Digital transformation in HEIs goes beyond new technologies in learning and teaching. It is an academic, curricular, organisational, and structural innovation, as these technologies enable new roles for teachers and learners, the last searching and achieving more autonomous and collaborative roles (Bond et al., 2018; Fleaca, 2011).

3.2 Beyond Research

Digital transformation is aware of learners, teachers, researchers, and people who work in or with HEIs. These individuals have to reposition themselves facing the new way of working for the digital transformed HEIs business and society, with new behaviours facing education and research. New digital technologies contribute to the academic perspective concerning the promotion of research collaboration. This perspective is differential among HEIs with a competitive positioning in the academic market, searching for the best researchers (Faria & Nóvoa, 2015). HEI's digital transformation may offer researchers disruptive tools and approaches without time and space barriers, promoting agility in research and interactions with internal and external organisations (Bresinsky & von Reusner, 2018).

However, as a kind of paradox, the innovation in research brought by digital transformation processes also changes individuals, groups, behaviours, and processes. These changes may affect the power relationships among departments, institutions, or both. Innovation and research require attention, sensibility, and care, as people that are researchers, sources of innovative behaviours, and creators are paradoxically resistive to change.

Digital transformation may become an active support component of research and innovation in HEIs; therefore, two simultaneous issues need to be considered:

- One internal to the HEI, which is the innovation of HEIs operations and structures as a meta-transformation. A perspective that considers the HEIs processes to deal with the challenges and opportunities to support learners, teachers, researchers, and staff, facilitating their relationship.
- One external to the HEI, which enable and reinforce the HEIs role as enabler and motivator of research and innovation. It is a perspective that considers the HEI's process to bear the business as a whole. The institution takes part, as the society in its many forms: industry, companies, institutions, and public image.

The internal issue is related to how digital transformation in HEIs can maintain the autonomy to perform research, innovation, and entrepreneurship. The external issue is related to research opportunities and engagement of HEIs with the market. The last has some reservations from the academics, as the private sector may focus innovation to specific economics sectors or private demands, strengthen the research opportunities, or deal with society's misunderstanding or misleading behaviours limiting the autonomy of research actions and results.

3.3 Beyond HEIs—Business Entities Relations

HEIs face a disruptive scenario established by digital transformation in businesses, which changes the traditional industries and, with the same principles, rethinks the business and rethinks where is the business. A scenario in which there is a dynamic relationship among all the players, internal and external to organisations, increasing commitments and potential conflicts strengthening individual autonomy and potential social influence.

Digital transformation in the business entities demands new professionals and recycle and extension programs for old ones. The role of HEIs in society demands that these institutions provide professionals to the productive sector. However, it is not an easy task. The Fourth Industrial Revolution imposes new paradigms, demanding HEIs to develop curriculum modernisations, satisfying new pedagogical methods and technological possibilities, personalising courses and experiences according to the restructure of the working process (Bresinsky & von Reusner, 2017; Fleaca, 2011; Panichkina et al., 2018; Rodrigues, 2017; Stolze et al., 2018).

Curriculum modernisations, flexible curriculum, or even minor changes in HEIs curriculum are not only a technical issue; it is also under the current structure as described when rethinking the business (Sect. 2.2.1, above). Moreover, legal issues bring implications and consequences in HEIs management, practices, and processes (Petersen, 2009). Diaz-Barriga and Barrón (2014) state that curriculum changing constitutes an intervention action, as it mobilises imaginations, power relations, different ways of participating, and positions within the institution.

University business entities integration enables a useful new world that allows numerous advances in various fields of humanity. The digital revolution experienced is intense and causes extreme changes in individuals' lifestyle, culture, and society in general. On the other hand, this integration allows HEIs partners to access a massive amount of data and information that can bring consequences to HEIs professionals. Rodrigues (2017) states that digital transformation challenges HEIs to implement the necessary level of security data, compliance, and regulations.

4 Night Tigers

Digital transformation impacts the HEIs as a whole. It challenges stakeholders, from learners to society (Benavides et al., 2020). The education sector, in which HEIs are a relevant player, is characterised by intense competition, a continuous search for market niches, and quality in learning, teaching, research, and integration with productive sector and society. The same technologies that support the digital transformation of current HEIs players are the key factors of new educational organisations in the competition to attract students and market opportunities (Navitas Ventures, 2017).

There are different ways to implement digital transformation. Benavides et al. (2020) present a systematic literature review that brings several examples. Rof et al. (2020) bring several references arguing that HEIs face challenges similar to those encountered in other business sectors, and it is possible to overcome tensions in HEIs. However, HEI's context has specific characteristics that are often not considered. They are night tigers: strong adversaries but invisible on a day-to-day basis, or, paraphrasing Rost and Glass (2011), they are the dark side of HEIs transformation. They challenge the digital transformation process:

- **Disruptive rivalry**—Digital transformation is how HEIs reorganise their structures and processes to better fit their learners, teachers, researchers, and staff in the Fourth Industrial Revolution context. However, in the HEI's environments, the strategies to implement digital transformation suffer from the continued competition between the institution's top administration and the academic staff (Meyer Junior et al., 2018).
- **Reality distortion**—Digital transformation aims to transform HEIs to reach the actual demands of the society. However, HEIs need to take care of the rupture between the transformation strategy and academic autonomy. It is the academic staff who must transform their classrooms, the way that learners learn, and transform how they interact with society. There are tensions between HEI's top managers and academic staff related to intentions, organisational complexity, political contexts, and the loose interrelationship among departments and laboratories. Léon (2018) argues that these tensions are relevant in Latin America, resulting from low coverage and quality due to inequities and socioeconomic gaps.
- **Gap hinder**—Digital literacy of HEI's stakeholders is another challenge. HEI's learners are young people—future professionals—and old professionals who need to recycle or extend their knowledge. It is a diversity of digital skills and behaviours that demands different approaches (Rodrigues, 2017).
- **Status-quo lingerer**—Another challenge present to traditional HEIs is to change the existing business (branding, rankings, specialisation). Traditional HEIs need to deal with digital transformation changes to avoid becoming "the dinosaurs of education"; the building processes are a continuum construction for the future (Kaplan & Haenlein, 2016).

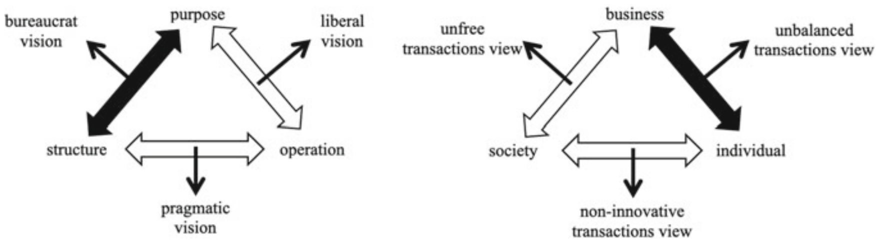

Fig. 4 Highlighted edges identify the situation favourable to the appearance of the disruptive rivalry. To deal with this situation, HEIs must privilege the purpose and operation, seeking a more collaborative, liberal approach

These are common challenges to all institutions facing digital transformation. It is necessary to deal with these night tigers rethinking the business and rethinking where is the business, which allows building a balanced position fostering an effective strategic vision to a digital transformation.

5 Discussion

Any solution addressing the night tigers is a complex and challenging effort to reinforce both triads (Figs. 2 and 3) in complementary directions. Moreover, any effort faces hidden resistance, much more than expressed and clear positioning.

5.1 Disruptive Rivalry

The disruptive rivalry is at the same time a change confronting the institution bureaucratic vision and unbalanced transition view perceived by the individual. Consequently, any opportunity that appears to foster a more liberal vision attracts the individual, whether a researcher, teacher, or student, independently of HEI purpose (Fig. 4).

To react against this perception, HIEs need to empower and gain commitment to their purpose and operation, which is a driver that can attract professionals with similar values.

5.2 Reality Distortion

HEIs do not receive immediate and robust feedback from the market. HIEs have a bias to perceive the world according to the individuals' position and opinions that they

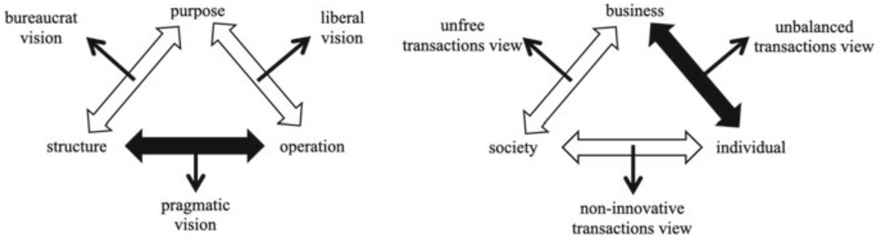

Fig. 5 Highlighted edges identify the situation favourable to the appearance of the reality distortion. To deal with this situation, HEIs must privilege business and society, seeking a less open view—reflecting society's demand

encompass (Fig. 5). This bias of reality varies according to HIE's interpretation and influences that can be originated internally (such as ideology or political positions) or externally (such as funding and patronage).

Implementation of digital transformations processes needs to face this bias. Therefore, HEIs need to develop efforts to compensate and realign their operation with what is perceived as an unfree transaction view that reflects the society and the business. A challenge is that the HEI's people with a biased view of reality are usually the same group with the power to foster digital transformation.

5.3 Gap Hinder

The generation gap brings conflicts related to knowledge and experience, and time to act, which opens up a pitfall among professionals in all organisations. HIEs, by nature, are the typical environment in which these gaps are presented; traditional researchers and young new professionals are the archetypes of this conflict. The generation gap impairs the transmission of knowledge and experience and stimulates early drop-off of young professionals (Fig. 6).

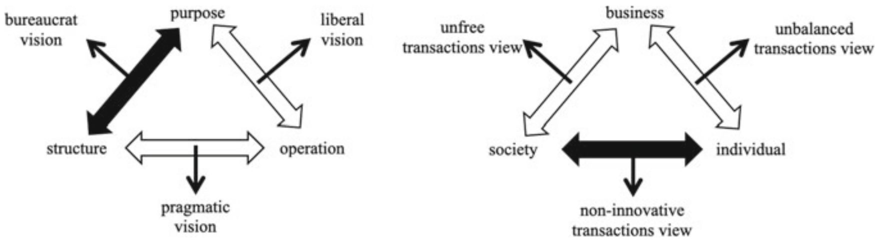

Fig. 6 Highlighted edges identify the situation favourable to the appearance of the gap hinder. To deal with this situation, HEIs must privilege purpose and business, fostering a more liberal or bureaucratic view and a more unfree or unbalanced external view

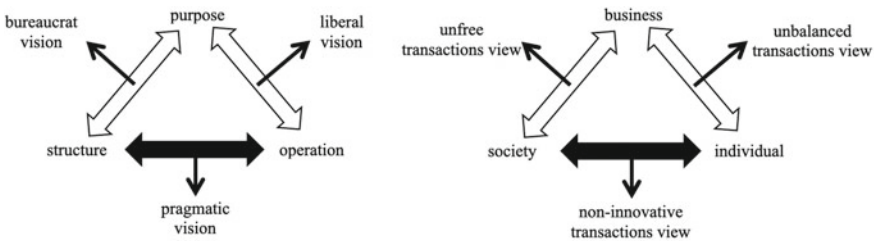

Fig. 7 Highlighted edges identify the situation favourable to the appearance of the status-quo lingerer. To deal with this situation, HEIs need to privilege an external vision: business and society (unfree vision)—focusing on the purpose and operation for a more liberal vision

The middle point to revert the generation gap is to rely on the purpose and business vertices of the two triads; only sharing the purpose and the business will be possible to attract both sides of the gap. Transactions will always be perceived as unfree or unbalanced by both sides of the gap regardless of a more liberal or more bureaucratic vision.

5.4 Status-Quo Lingerer

Status-quo Lingerer is probably the more common and one of the hardest to supplant. It is a natural behaviour that is hard to differentiate between a natural and reasonable reaction to change and a stubborn passive–aggressive reaction to change. Inaction is a typical behaviour. It reinforces a particular pragmatic vision that maintains the current status quo with non-innovative efforts (Fig. 7). An individual can always fall back to a position where he or she considers himself or herself in a weak position vis-a-vis a strong business, or as a professional limited in action due to defined processes.

In such stalemates, a possible approach is to encourage the need to foster a liberal vision, valuation of the business purpose with an efficient operation, and maintaining control through a set of new defined transactions.

6 Conclusion

The Fourth Industrial Revolution brings significant opportunities, challenges, and complexities to HEIs, which need to prepare individuals to work in this new context and harvest the benefits of technology. It is a socio-technical context in which the technological determinism imposed by the traditional rational and linear thinking does not allow complete success. This approach considers that people and society are only components of a system without values and desires.

There is no silver bullet or complete analyses that assure a successful digital transformation, even more on Latin American HEIs dealing with the more than necessary researchers' autonomy. The double triad models "rethink the business" and "rethink where is the business" create an integrative framework, a strategic playing field to understand, manage, and overcome the challenge of dealing with adverse digital transformation scenarios. Our open analysis proposal in a strategic playing field allows a constructionist approach to dealing with perceived and covered forces and agents. Digital transformation is business decisions following business strategies, a heterogeneous set of processes and practices to improve business efficiency as a whole.

It is necessary to not fall into the temptation of implementing digital transformation only in some departments or HEI's administrative areas. It is needed to address those professionals whose autonomy and independence are the keystone of the quality and innovation of HEI's research and, at the same time, prepare the needed new professionals and researchers to support the Fourth Industrial Revolution.

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Education in Latin America: Toward the Digital Transformation in Universities

Amadeo-José Argüelles-Cruz, Francisco-José García-Peñalvo, and María-Soledad Ramírez-Montoya

Abstract Education in Latin America turned to the use of distance communication strategies in the scenario's face of health, social, and economic consequences resulting from the COVID-19 pandemic. This abrupt change meant reviewing a set of conditions that drastically affected quality teaching and education in the region. This chapter addresses the conditions that universities in Latin America countries must face in order to ensure that their students can develop quality knowledge through the conditions present in distance and hybrid models, and the efforts that must be concentrated on in teacher's training, in order to professionalize in a more innovative manner in the face of digital and remote teaching. The factors that universities at the region should consider in their models to address the relevance and encourage the development of activities to meet their objectives and those of the community in which they take part. In the same way, the metrics, indicators and data for the areas of opportunity and the analysis of information used for decision making will be reviewed, and the use of artificial intelligence, Internet of Things, big data, data analytics, cloud computing and the complement information and communication technologies required in the digital transformation of the universities in the Latin America region.

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Keywords Digital transformation · Hybrid systems · Latin American universities · Key performance indicators · Artificial intelligence · Cloud computing · COVID-19 · Educational innovation · Higher education

1 Introduction

When we refer to the transformations that were generated in economic matters and that were the trigger to offer education to society, we can allude to the very origin of the educational institutions in the continent and the role they play to provide the workforce to attend the demands of the society throughout the time. The first universities founded in America, created by papal bull, royal charter or royal provision, were the Royal and Pontifical University of St. Thomas Aquinas in 1538 (Dominican Republic), the Royal and Pontifical University of San Marcos (Royal University of Lima, Peru) founded on May 12, 1551, the Royal University of Mexico in 1551 and the Royal University of La Plata, imported models of knowledge dissemination and influenced from the prestigious Universities of Salamanca and Alcalá de Henares, which together with the blending of the population, led to the development of an educational model with a political–religious function (Albornoz, 1993; Rüegg, 1996). This model had as its economic support the trade of raw materials, driven by the development of technology to improve maritime traffic and as a bridge for the dissemination of ideas with the use of printing developed in the mid-fifteenth century (Marichal, 2019; Topik et al., 2006). Then came the conditions for the changes in the way of observing the world in the educational context with the arrival of the illustrated reforms coming from Europe, which defined the cause of history in the sixteenth to eighteenth centuries and which were the origin of an important effect in the economic and social context of the time, with the globalization of the economy that developed from the early days of the European presence in the region (Marichal, 2019; Topik et al., 2006). Latin American economic historiography reports on various socioeconomic and political transformations that have influenced and shaped the current state of nations in Latin America and the Caribbean for more than two centuries, and which have led to the development of industry, trade and the telecommunications sector, which are the engine that drives the economy and whose technological effect, at first at the hand of the typewriter or the blackboard and later on the computer, digital screens and information and communication technology, which for the first time linked the university to the productive apparatus of nations. But let us take a closer look at the changes that have occurred and that will become, whether we like it or not, close to the time when this chapter was developed. The transition that marks the development of humanity is strongly linked to the society of knowledge and the use of data.

When we place ourselves in the second half of the twentieth century, we observe the unfolding of economic globalization, from which derived the globalization of knowledge that began to transform the way of thinking of the university and its management. A series of reforms aimed at responding to new market demands.

Chile in the 1980s with the integration process open to globalization or Mexico in the 1990s with the free trade agreement and the South American countries associated with Mercosur. Along with the restoration of democracy in most Latin American and Caribbean countries, a series of state reforms were carried out. At the same time, a debate on higher education was spreading throughout the region, which made it possible to visualize the effects of the aforementioned reforms, among others, the notable expansion of student enrollment, the reduction of public investment in the sector, the rapid multiplication and diversification of institutions dedicated to providing different types of post-secondary education, the growing participation of the private sector in the composition of educational offerings, and the progressive distancing of the state from its responsibilities in the financing and regulation of higher education (Tünnermann-Bernheim, 1996).

The society of the twenty-first century as a whole has its attention focused on the knowledge economy and global economic competition, using the sources of information and the knowledge developed to generate wealth through a greater and efficient use of data, in addition to placing its attention on innovation as a differentiating element. There is a long way to go in the region and whoever succeeds in joining these areas will determine their future well-being. In this regard, quality education, lifelong learning, and the provision of equal opportunities for all can help people compete in a global economy by creating a skilled workforce and facilitating social mobility. One of the supports to address the above is undoubtedly access to information and communication technology (ICT), which provides opportunities for people to develop learning and build new skills, allows the incorporation of communities living in remote locations with little or no approach to education, facilitates and improves teacher training, and reduces costs associated with the provision of education in the long term.

However, the technological transformation does not rely completely in technology. It is related to having better and more prepared students. In Latin America, there has to be a competitive industry that comes from innovations in schools by assimilating digital technologies and a new industry vision. This can only be done by combining the ideas of technologies, by making interact with each other to offer complete solutions for the problems of the new world.

This change of paradigm can be seen in several areas where products are made by robots or machines, with algorithms of artificial intelligence designed to make decisions and communicate with other machines. In Latin America, companies and schools that develop and use these technologies already start to appear from every sector and conditions.

The socioeconomic crisis caused by the COVID-19 pandemic makes it more urgent than ever to generate a new economic and social development model. The digital transformation is a powerful tool to overcome the structural challenges of the Latin American and Caribbean region, considering as a key point the development of policies for the generation of new sectors, quality jobs, capacity building and innovation.

The scenario provides the momentum for the application of reforms toward the use of the benefits of digital transformation provided by the Fourth Industrial Revolution.

This can help to face the adverse conditions that the arrival of COVID-19 has made more profound than they were for the economic condition of the region.

But there is the opportunity of the wind of change through the implementation of digital transformation to get out of the crisis by stimulating new consumption models that helps environment at the same time, transforming production systems and values chains, applying business innovation, and introducing new competitiveness formulas. Digitalization can support better access to health, education, security, and other required services. Digitalization places citizens at the center of policymaking that can help to improve governance.

In the end, there is a unique opportunity to boost productivity through the power of knowledge provided by the digitalization and the implementation of quality educational services that support the required changes at the region.

2 Overview of the Latin American University Education Activities Under COVID-19

COVID-19 pandemic arrives and increases the relevance of digital technologies to face the isolation, providing the support for the continuous operations of the health, education, and economical systems. Mobile applications and information and communications technologies are being used for the diagnostic, control, and mitigation of COVID-19.

In that order of ideas, COVID-19 collapsed the face-to-face educational system to solve the necessities of the students to receive classes throughout universities infrastructure without interruption and trying to cover academic services to the community under sanity alertness. Professors lack the ways to attend students with tools they do not manage and need to step up the learning curve to overcome the situation in a short period of time.

The faculty made an effort to modify their pedagogical mechanisms to adapt to those of tele-education, seeking to keep the school period running, incorporating tools that would allow them to face the health crisis and continue their teaching activities in the remote mode by responding in a short period of time. The lack of evaluation or accreditation instruments for student knowledge in a virtual teaching context made precarious the evaluation process.

In the case of the school administration, the administrators faced a number of different situations, such as the coordination of the teaching of classes in the remote modality, the management of the admission and registration processes, the attention of students with diverse needs to maintain connectivity in order to receive the education of the programs in which they were registered, among other present issues derived from the pandemic.

The conditions of the telecommunications infrastructure and digital connectivity to be able to meet the needs of the population in terms of tele-health, tele-education, and tele-working were put to the test. The indicators that were considered in the challenge were the exponential increase of Internet traffic, which caused the operators that provide the connectivity to maintain the quality of service also for the productive sectors, supply chains, and distribution of goods.

Given the condition of the health alert, the governments of the region carried out a series of public policy and regulatory actions to facilitate the population's access to official information and distance education services. This allowed students to continue their academic training from their homes. The following are some regional measures to address educational activities related to university education:

Argentina: A moratorium on debt payment was applied to citizens who have no income or live from informal jobs for up to three bills on fixed and mobile telephone, Internet, and cable TV services. This is to meet communication needs during the health contingency period.

Brazil: The Ministry of Education (MEC) took some measures to reduce the risk of contagion and determined that public and private universities will be able to replace face-to-face classes with online classes. MEC also expanded the capacity of web conferences in universities and federal institutes. The total service capacity of 1700 simultaneous accesses now stands at 10 thousand.

Chile: The government implemented a solidarity connectivity plan at no cost for 60 days for the lowest income customers. This plan will allow beneficiary families, free of charge, to surf the Internet, use social networks, answer emails, access official sites related to COVID-19, and other services. The connectivity of this plan will not be able to be used to consume streaming or video games. It also decided to promote tele-education by the Ministry of Transport and Telecommunications (MTT), through the Undersecretary of Telecommunications (Subtel), the Ministry of Education (Mineduc), and the Mobile Phone Association (Atelmo) so that students can access the site aprendoenlinea.mineduc.cl for free and continue studying despite the contingency of COVID-19. In addition, both students and teachers from places that receive state subsidies will have access to the school digital library with more than 10 thousand books available.

Colombia: Conditions are set to manage Internet traffic to allow users to consult health, emergency care, official, labor, and educational information. A rule is included so that video reproduction platforms on the Internet do so on a standard format, which is not high definition or higher. The Ministry of National Education (Mineducación), in conjunction with RTVC, the public media system, created an alliance to broadcast educational content aimed at children and youth throughout the country; in addition, the broadcasts will be available for download on RTVCPlay's digital platform.

Mexico: Ministry of Public Education (SEP) and Microsoft agreed to provide teachers with access to the Teams tool to organize 28 work and distance training sessions, from their preventive isolation.

In 2020, a population of 629 million Latin Americans is reported, of which 467.82 million have access to the Internet (Statista, 2020). 25.6% of the population in the region lacks the opportunity to access the Internet for activities such as access to information and government, banking, commercial, and health services, among others, which are supported by ICTs. This inequality is present in adults and young people, between men and women, between urban and rural areas. To reduce the digital gap, it is estimated that the region requires approximately 160 million dollars in direct investment.

The coverage that exists in the region can be observed, but the asymmetry in access to broadband, the quality of access to content and the high cost of data traffic flows stand out as a whole. It is essential to cover the digital gap present in the region for the next decade, carrying out efficient and effective work in areas such as the deployment of digital infrastructure, institutional modernization for the digital economy, the development of digital industry, the digital inclusion of households and businesses to improve the quality of life, the digitization of production of economic sectors as well as digital public services of the state's public administration. With this, the fulfillment of the digital agenda will be able to offer a frame of reference of how each country faces its capacity of response to the opportunities of progress and quality of life in Latin America (CAF, 2020). The adjustments to be developed in terms of digital transformation in the region can generate growth of 3% per year.

The challenge of the economies in Latin America is strongly linked to education for sustainable population growth. By 2030, the goal is to close the digitalization gap recorded by the OECD, which means generating productivity growth of 3% per year. The record referred by ECLAC for the region related to connectivity coverage, at the end of 2019, is 66.7% (CEPAL, 2020; Naciones Unidas, 2030).

3 Requirements of Digital Transformation

The concept of digital transformation had a different connotation from the one considered in these moments of pandemic. Previously, higher education institutions were looking to make it possible to register remotely and for students to have the opportunity to do so not from their homes but from ATM-style terminals in the cities to withdraw money, so that they would have the opportunity to develop the registration process remotely.

Later the next milestone was how to digitize the libraries, indicating how the library and bibliographic collections could be accessed through digital mechanisms, even having digitized and scanned or having more modern digital versions. However, these issues are not the fundamental elements of the transformation that higher education institutions are facing now, or at least the concept of transformation would surely not be understood in the same way. At this time, the digital transformation of higher education institutions has two very clear aspects. One is administrative, where the administration of the institutions must use everything that technology provides to be much more efficient, for example, considering technologies like blockchain to ensure that files can be tracked and accessed from other institutions from anywhere in the security guarantee and the technological effort that is great to attend the emission of certificates and diplomas (Bartolomé et al., 2018).

The second aspect is to transform the teaching environment or the teaching and learning environment. Our last fundamental mission as teachers is to make students learn; therefore, we cannot separate the concept of teaching from the concept of learning because it is intimately linked, especially if it is an institution that develops people to achieve their personal goals. In this sense, the digital transformation that institutions are considering should not be based on a technological change but should include a conceptual and mental change.

Educational institutions solve their transformation following an evolutionary process, where they try to add new elements and maintain tradition. But this causes that the changes they seek to attend are made at a much lower speed, it is as if in the journey to a destination a load is carried inside a container that houses traditional practices that make it difficult to maneuver a unit that seeks to circulate in a high-speed highway. We must look at the digital transformation of higher education institutions from another perspective, where the condition of presence has been the main component, then non-presence and last but not least a mixed condition or mixture of both, attending to the naturalness of the audience to which the efforts of each institution are directed. Given the eventuality of the COVID-19 pandemic, the presential model is not viable, and it seems that the strategy should be oriented to consider the online or mixed perspective with a permanent and dynamic transit look and not only to solve problems to get out of a difficulty, because with a high probability they will touch other similar contingency scenarios in the future and with uncertainty in their temporality, because the human gender has strongly influenced the ecosystems and the climate change of the planet.

4 Digital Transformation of the Institutions

A higher education system can be analyzed in three different stages: the entry, the process, and graduation. Entry and graduation are usually the critical points in the analysis of higher education. Who enters, under what conditions does a student enter the institution, what requirements must be met, what is required as an applicant, among other requirements for entering higher education. When taking the side of student entry, the objective is to measure the student's potential to make progress in the process. In the case of graduation, the potential of graduates to enter the labor market is measured. But the most important thing in college is neither entry nor graduation, but the learning process is to be achieved. All this is connected to the fundamental division of the education society (the university practices of the twentieth century) and the knowledge-and-learning society (the universities of the twenty-first century). In the first, the important thing was graduation, the training of human resources to meet the demand of the labor market. From the point of view of the knowledge society, the important thing is the learning process, the dialectic of the relationship between three elements: the student, the teacher, and the knowledge, and of course, the second one has to do with the technological platform. In the knowledge society, the technological platform allows today to extend the parameters of that society to an extraordinary scale that in the last 15 years, the contemporary university has a more advanced knowledge than in the rest of its history (Jiménez, 2007).

From this perspective, what is happening now with the use of the technological platform is that there are many variations of the learning process. Students are given the opportunity to access vast amounts of information and content like never before, because they have at their fingertips incredible tools to be able to not only carry out their instruction but also have the capacity to make innovations. The support provided by technologies such as big data, the Internet of Things, mixed reality, artificial intelligence and cloud computing leads to new territories of knowledge to be explored for those who wish to do so. Of course, we must consider that the democratization of access to information is a pending subject for universities and in turn for the governments of the region.

As the years go by, more digital native students will go to university, allowing the act of learning to focus more and more on the content and not on the platforms that support operations to develop learning. In the case of the faculty members, they will be able to rely on advances in technology to monitor each and every one of the students to achieve the goals and objectives of the study programs. The digital transformation, in this sense, can focus on developing the digital infrastructure that houses the contents that are taught in the courses and implement monitoring mechanisms in the evaluations of the knowledge acquired individually by each student. Said digital structure can be helped by new technologies that bring the learning experience closer to the real conditions that students need to understand for their best performance when entering the labor market.

For example, the use of mixed reality can help in the development and understanding of knowledge for healthcare professionals in the field of robot-assisted surgeries, the use of the Internet of Things to record the behavior of an administered drug, to the patient online, or drug simulation using cloud clusters to speed up computing and get results faster, among others. If we think of operational samples of technology 4.0, there are opportunities to learn process management by using digital twins in applications such as agricultural tractors to change their operations in planting seeds or change the conditions of fertilization in hydroponic crops in greenhouses.

In the development of the monitoring of the student's trajectory, artificial intelligence is an ally in carrying out the work of sustaining the level of quality that is aimed at, since it focuses its value on improving over time the considerations that are made about teaching–learning processes, such as early warning of the student's condition in situations that compromise learning activities. To achieve this, it is necessary to carry out training actions for teachers, administrators, support staff, and assistance to education, in several of the areas involved with digital transformation. Understanding the potential of current and future digital technologies, their potential risks, and threats is essential for the development of universities in the region.

The best understanding of digital transformation is adopting processes and practices to help both public and private universities organization and companies involved with digital transformation and the Fourth Industrial Revolution to compete effectively in an increasingly digital world.

This definition of digital transformation has two important implications for managers (mainly CEO an CIO): First, it means that digital transformation is fundamentally about how your operations respond to digital trends that are occurring whether or not you initiated them, like them, or want them.

Second, it means that how universities and companies implement technology is only a small part of digital transformation. In cases where digital transformation does involve implementing new technologies, the technology is only part of the innovation process.

The digital transformation requires that institutions, and all its workflows and org charts be transformed in order to build and sustain digital services. Thus, there is a clear need to provide capacity building to all stakeholders in various areas associated with the digital transformation. The understanding of the existing and upcoming digital technologies, their potential, benefits, threats, and pitfalls is essential to become an integral part of this transformation that is taking hold in the region.

Higher education institutions can improve their educational actions by taking advantage of the flexibility of moving between models that are completely face-to-face and completely online, in accordance with their own vision, with the profiles of professionals who want to produce and with the strategies to make adjustments to achieve their goals and objectives. It is possible to generate a transition that has the scenario of providing the service according to the installed capacity or according to the profiles of the community registered in their study programs. This leads us to think that a mixed or hybrid model can cover a wider range of profiles and better adapt to the conditions that higher education institutions may face in various conditions. For example, programs can be offered where students can take a face-to-face percentage of their curriculum and another percentage online. This model has the flexibility that allows students to define, according to their life circumstances or capabilities (distance from the facilities, economic resources, travel times, learning skills, security, among others), what the alternative is for them to complete an academic degree. This increases the educational offer that a higher education institution can provide to the community it seeks to serve in its formation.

Weeks before the COVID-19 pandemic declaration, which took place in March 2020, several universities in the world announced the decision to change their activities (courses, admission exams, mid-term and final exams, graduation exams, events, conferences, lectures, among others) to the online modality, this for the conclusion of the school year 2019–2020. Some face-to-face universities have taken steps to put their curricula online. One of the first to attend the problem was the University of Cambridge in the UK, which announced plans to switch its face-to-face lessons to online digital lessons, including videoconferencing and seminars, for the 2020–2021 school year within 2 months of the official declaration of the pandemic, in line with the requirement of healthy social distance indicated by the national health system (The Guardian, 2020).

It should be noted that offering online courses is not an easy task. In the operational part of the face-to-face models that have changed to the online mode, it has been a complicated change. In principle, the teacher who conducts a master class does not have within his reach, in most cases, the information and communication technologies that support a transition to online classes.

5 Cases of Digital Transformation in Latin American Universities Within the Framework of COVID-19

The co-financing as a result of COVID-19 demanded that universities change their practices, demanding digital transformations of educational innovation for all their processes, in order to continue with quality processes. Valencia and Valenzuela-González (2017) indicate that the objective of educational innovation is to generate a product, a service, or a solution that involves integrating a novelty in an existing reality, modifying its being and its operation, so that its effects are improved. In times of crisis, educational institutions face challenges to academic continuity.

Digital transformation and educational innovation have a very specific link. A recent study in Latin America reflected changes in digital transformation within the framework of COVID-19 (Ramírez-Montoya, 2020a), and, for the purposes of this chapter, they are grouped into the three levels of quality of institutions, proposed by Rodríguez-Abitia et al. (2020): technological, pedagogical, and organizational, where contextual factors play a determining role in the capacity of an institution to take advantage of technologies to help the educational process and guarantee its quality. Below are ten cases from Latin America where the challenges of digital transformation and requirements for educational innovation are set out (Fig. 1).

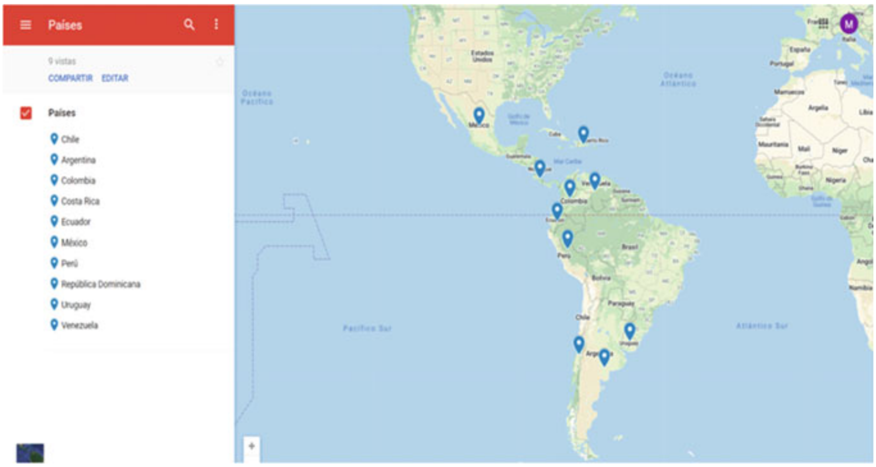

Fig. 1 Cases of digital transformation and educational innovation within the framework of COVID-19 (Ramírez-Montoya, 2020b)

5.1 *Report of Cases with Technological Changes*

Venezuela case. The university under study is public, created in 2003; it has 12,777 students and approximately 2200 professors. They face a great challenge due to the limitations they are exposed to and due to the economic blockade they are undergoing, which makes it difficult to access basic and specific resources to carry out their teaching work, such as: acquisition of fixed and mobile equipment, paid connectivity, and of course salaries that do not cover the basic food basket. The permanent electrical sabotage, besides limiting the use of equipment and its connection, has also limited the use of the institutional platform, since in some cases it implies the suspension of the service and the offline use of the virtual teaching–learning spaces of the institutions. In educational innovation, there is a need to systematize innovative experiences with positive results, projecting the mass use of ICT in a conscious way, not as an end, but as the most appropriate means to massify quality education, making strategic alliances with other university education institutions nationally and internationally.

Colombia case. The university under study is public. The main challenges faced by the university with COVID-19 were the appropriation and use of technology by teachers for the normal development of classes. In the specific region of southern Colombia, connectivity and access to the use of electronic devices are limited for certain population groups, due to geographical and economic issues. A large percentage of students are from low socioeconomic backgrounds. The challenges of digital transformation for the return are the physical infrastructure like classroom spaces with secure distance between students and professors. In relation to the technological infrastructure, pending issues regarding services and available resources for quality connectivity must be resolved. The adaptation of professors to teach in hybrid or online educational environments must be included in other challenges to be addressed in the university related to enrolment and teaching management in the new post-pandemic environments, the culture of innovation, the implementation of technological solutions for digital transformation and those aspects related to research processes.

Ecuador case. The university under study is private, was founded 49 years ago, and has approximately 35,000 students and 2000 teachers (800 of which are basic and 1200 guests). The disadvantage, not only as a university, but also as a country, was the level of Internet connectivity. Information was collected through a survey during the first two months of classes and 70% of students connected to their classes without problems, and 30% had problems doing so for various reasons (they do not have a computer, they do not have access to the Internet, among others). In innovation, they reflect that among the aspects they consider should be improved are the technological infrastructure and the evaluation processes, since these two topics were presented as the greatest areas of opportunity and the experiences obtained will serve as a basis for improvement.

5.2 Report of Cases with Pedagogical Changes

Uruguay case. The university under study is the first public university in the country, founded in 1849. Its population is around 150,000 active students, 11,500 teachers, and 6300 technical administrative and service positions. They worked with a plan for online teaching and learning in emergency conditions. The plan consists of four dimensions: (1) online teaching and learning in emergency conditions; (2) redesign of online teaching and learning; (3) adaptation of digital systems to increased demand; (4) communication strategy. They detect that educational innovation must be critical and contextual.

Costa Rica case. The university under study is public, was founded 42 years ago, and has approximately 35,000 students and 7000 professors. With regard to the digital transformation, the need for an agile response is the most important, because now students and professors require that the support entities (production of materials, administrative, editorial, technology services, and those in charge of the platforms, among others) be much more efficient in responding to the requests made of them by the faculties, but also that the solutions they propose be relevant and in accordance with the situation. In addition, the training of teachers in the use and maximum exploitation of synchronous tools is also very important and necessary. Innovation in teaching, supported by research, and the detection of best practices that are being proposed in the face of this pandemic are essential to adapt to the new reality.

Mexico case. The institution under study is public, founded in 1922, is 98 years old, and has 26,000 students and 1000 teachers (780 full time). They detect that of the challenges of digital transformation that the university will have to face when it returns are (a) the lack of training of many professors to work in a completely online environment; (b) improving the technological skills of professors to work online; (c) the lack of access to technology by some students. They recognize that a great technological gap exists since not all students have access to the technology needed to take their classes online. The aspects of educational innovation to work on are modifying the didactic plans of the subjects, training the teachers, improving the technological infrastructure, and developing support programs for disadvantaged students and virtual libraries.

Dominican Republic case. The university under study is public, founded in 1538; it has approximately 190,248 undergraduate students, 2480 graduate students, and a teaching enrollment of 3545 professors. The main challenges they faced at the university with COVID-19 were (1) the vast majority of the teaching staff did not have the digital skills to finish the semester virtually, so there will be a large number of students who will not be able to finish their subjects and will have to withdraw them; (2) the students did not have the knowledge to handle the virtual platform either, since most of them had never taken a subject virtually, and (3) the professors did not foresee how to contact the students once the state of national emergency was decreed, they did not have telephones or an e-mail address, which made communication difficult.

With respect to educational innovation, it is considered that innovation in teaching should be worked on, so that teachers master the platform and can develop their learning materials themselves.

5.3 Cases with Organizational Changes

Argentine case. The university under study is a public one, founded in 1956, and has approximately 28,000 students and 3200 teachers. They set out the challenges of digital transformation that educational resources should be extended, continuing with the training of teachers and professors in general, and incorporating teleconferences with guest professionals from other national and international universities, as well as from different fields. It would also be very useful to incorporate different tools such as simulators (e.g., virtual microscopes) both in the health and biological areas and in the engineering area, among others. It is recognized that there are several aspects of educational innovation to be worked on at the university, starting with innovation in teaching, generating, for example, more resources for teaching. Innovation in research is also considered relevant since, due to the pandemic, it has been significantly reduced.

Peru case. The university under study is private, with 103 years of foundation, has 23,227 undergraduate students, 5971 graduate students, and 2600 professors. Organizational changes are required to strengthen teacher training for the preparation of their own educational resources, and that these can be housed in the institutional repository to support their subject matter or other related ones. At the motivational level, there is a strong demand from a group of teachers and students, who demand more spaces to socialize, so that spaces for exchange must be generated, allowing the development of extracurricular activities that are highly valued by the entire community. In innovation and management, it will be necessary to combine staggered attendance, thus avoiding the conglomeration of students.

Chile case. The university under study is private, has been in operation for 30 years, and has 15,000 undergraduate students, 1700 graduate students, and approximately 2285 academics. One of the main challenges is to ensure the practical training of students, especially in careers linked to health and education, since given the extensive quarantines and the suspension of classes in the school system, this training has been replaced or postponed. In addition, it is desired to privilege the experience with higher grades of face-to-face classes in first year students who have not had university life experience properly. To this end, a hybrid system with both face-to-face and online classes was piloted (before the mandatory quarantine), which poses technical and logistical challenges. As for the aspects of educational innovation, they state the need to manage academic processes considering different modalities at the same time. The challenge is to work "on different sides" being tremendously flexible and creative.

6 Discussion and Conclusion

The conditions to attend the digital transformation on the region are daunting, and public and private universities must attend their expectancies to solve problems from different perspectives but with a common goal: The students are the core of the activities, and the reason to continue the efforts to overcome the situation COVID-19 is pushing toward new ways to attend not only health but also incorporate innovation to overcome adversities and enhance the performance in all the front activities the services provided to learning community.

The situation of confinement caused by the pandemic has generated a difficult economic, social, and political environment for the region. However, decision makers in Latin American countries can take advantage of the moment to impulse public policies aimed at the education sector that promote a favorable environment for the use of digital transformation in education and the appropriate and conscious use of artificial intelligence in the development of activities in classrooms and laboratories, and the management of school processes throughout the educational sector.

Digital transformation can enrich and make the educational process efficient through the incorporation of technology and application of innovative solutions in all areas of education. Attending to good practices such as the correct use of social networks for the understanding of the natural and social environment, the benefits offered by mobility to solve problems of desertion or absenteeism, or being tied to physical locations and schedules, promoting the ubiquity of education as a support to communities less favored by their economic, social, or geographical situation. That the use of new technologies be conceived from the point of view of stimulating learning, thanks to the processes of personalization of teaching. That it is learned that the improvement in verbal and written communication of ideas and knowledge that students absorb in their daily learning occurs with the responsible and balanced use of the technology used in the classroom and outside it.

Good practices will be important in this context, driven by the transformation of educational processes, the use of platforms based on virtual learning environments with digital content appropriate to the educational context, the use of data analytics and big data in adaptive and personalized learning, supported by artificial intelligence and gamification, support for the integration of communities and rural centers with hosted work environments and supported with cloud computing, standardization of online assessment systems, all supported by the privacy of student and teacher data, among others.

The disruption caused by the digital transformation and the one generated using artificial intelligence in education are a reality of the digital world that must be taken advantage of, since the education and training sector is intimately linked to the processes of digitization and transformation driven by the new models and ways of doing things in the knowledge society. Despite the efforts, in Latin America there still are barriers that must be overcome; according to Global Connectedness Index (CGI), it persists a problem of Internet connectivity in the region that countries must address before implementing those technologies.

Latin Americans must do their best to generate the right environment to offer better opportunities for the society of which we are a part and to strengthen the training of the next generations.

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State of Digital Transformation in the Universities of Central America

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Abstract The surprise arrival of the COVID-19 pandemic produced an accelerated transition in all educational institutions, forcing them to take advantage of digital technologies and the Internet to ensure that their operation could keep going. In this document, a study of various scientific articles, reports, publications, and existing documentation on the digital transformation processes launched in the different Latin American universities was carried out, presenting the methodological proposals promoted toward the new modalities of remote education, the reinvention of administrative processes, and the support provided to the university community to reduce the digital divide. An online survey was designed to know the advances in the digital transformation (DT) of 20 universities in Latin America. Outcomes of the online

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survey supply insights in four key DT objectives: teaching and learning, student support, research, and administration. Also, a case study of the implementation and monitoring of the DT model at the Technological University of Panama and its projections was considered.

Keywords Digital technology · Digital transformation · Higher education · Latin America, university

1 Introduction

Digital transformation refers to the process of optimizing, and transforming the institution's strategies, activities, operations, decisions, and value offers through a coordinated transition regarding the work culture and taking advantage of digital tools. As defined in (Grajek & Christopher Brooks, 2020), this process comprises three (3) sequential stages that are: (a) Digitization, the step from analog to digital, which includes digitization and organization of information. (b) Digitalization, the use of technologies to transform institutional operations, which includes the automation and streamlining of processes. (c) Digital transformation, the institutional appropriation of technological tools, which includes the cultural change of the workforce and the reinvention of production models.

In the university academic context, the digital transformation must be carried out through strategic planning that involves the reengineering of institutional processes, so that they are consistent with the digital context. It implies the integral participation of all the actors of the university community to adopt the new work methodologies, giving way to institutional innovation and the refinement of processes (Gaibor, 2020; Garcia-Peñalvo & Correll, 2020).

Another benefit of digital transformation in the university is the possibility of having the technological infrastructure and digital tools conducive to the implementation of business process management tools (Mora et al., 2020) and data analytics on the information produced from the development of academic activities (Nguyen et al., 2020). In this way, the ability to make better decisions on the adaptation of educational plans is obtained, and the monitoring and early application of adjustments aimed at improving teacher and student performance and streamlining administrative processes.

It is claimed that in this information age, the relentless advancement of information and communication processes has become the engine of social evolution, including educational transformation. The three main data analytics research streams are: Learning Analytics (LA), Academic Analytics (AA), and Educational Data Mining (EDM) (Nguyen et al., 2020).

According to the authors (Menéndez et al., 2017), the digital transformation of higher education institutions can be defined as the process of technological and organizational change induced in these institutions by the development of digital technologies.

2 Difficulties for Digital Transformation in Higher Education

From the teaching perspective, the greatest challenges that universities face in the digital transformation process include the lack of adequate training of staff in the use of technological tools, limitations in the Internet speed of the institution, and the university community, as well as the lack of spaces for planning and contributions of proposals for future technological development (Arias et al., 2021).

From the perspective of university presidents, the greatest challenges that forced digital transformation have implied on institutions which are inequal in the capacity of the technological infrastructure of some universities compared to others, and the skills of the staff to use digital tools. Other difficulties are the limited access of students to computing devices and the Internet, the paralysis of field research, the fragility of university financial sustainability, and the effects on the mental health of the university community during the process of digitization of activities (BID, 2020).

Among the fundamental axes that must be considered to promote the digital transformation process of universities are: (Didriksson, 2018; Goris, 2020):

- The training of the teaching staff and the university community in the use of technological resources.
- Establish reference frameworks that ensure the quality of virtual teaching.
- Guarantee equity and accessibility to educational material in the remote mode.
- Internationalize university programs in the face of international mobility restrictions.
- Strengthen research and development processes with participating entities outside the university in view of the limited access to laboratories that require physical equipment.

3 Background of Higher Education Institutions in the Face of Digital Transformation

According to data obtained by a study published in 2018 by the International Data Corporation (IDC) sponsored by Microsoft, there was already a trend of 76% of universities toward the use of digital technologies to provide learning anywhere. The main technological initiatives of interest corresponded to the use of information portals, coaching tools, better mobile access, and videoconferences, in that order of priority. The use of learning management systems was barely present in the perspective of 12% of the universities, with the most used modules being those aimed at productivity, assignment delivery and forums in 60% of use in each academic institution. For their part, 40% of the universities surveyed did not intend to apply Big Data and analytics tools in the management of their processes (Paredes-Chacín et al., 2020).

Globally, for the year 2019, the results of the study are also available (Ramírez-Montoya, 2020) carried out by the International Association of Universities to leaders of higher education institutions showed that:

- 58% do the student enrollment process completely online.
- 47% fully use a learning management system.
- 65% have privacy policies or ethical use of data.
- 79% state that technology is used to a certain extent in class, but not completely.
- 46% take advantage of mixing flipped classes and online learning.

4 Transition of Latin American Universities to the Digital Field

Taking as reference the results presented in research (Paredes-Chacín et al., 2020) and (Ramírez-Montoya, 2020), the measures implemented by the universities of different Latin American countries are presented in the face of the change in educational modality:

Argentina

- In the case of a public university, when the total quarantine began, all the programs were switched to virtual mode. Tablets and notebooks (based on a previously conducted connectivity survey) were distributed to students who did not have access to any device.

Brazil

- At Universidad de Estadual de Campinas, resources were increased to improve remote access to classes, such as loans of equipment and Internet access for students.

Peru

- At Pontificia Universidad Católica de Peru, a distance education platform has been designed with free classes and workshops for its students, and a connectivity fund has been set up for free Internet access to the entire university community.
- La universidad Peruana Cayetano Heredia presents the establishment of a continuous training program in the field of virtual classes for students, professors, and deans.
- At the Universidad del Pacífico, its institutional Web site was redesigned to keep the university community informed about news and protocols to follow in times of pandemic.
- In the case of a private university, virtual classes were integrated through Zoom with the use of a learning management system. An Internet scholarship was given

to 5000 members of the university community and a loan of 150 laptops to students.

Dominican Republic

- In a public university, it was necessary to enable the virtual platform for all the subjects of each academic program. The institution has the technological capacity to teach classes virtually, but both teachers and students needed training in the use of technological tools.

Chile

- At Pontifica Universidad Católica de Chile, workshops are held on virtual education strategies.
- In the case of a private university, a connectivity survey of students, teachers, and administrators was carried out, providing the equipment to those who required it, and online classes supported by an institutional platform as well as the adoption of Zoom platform for teaching.

Mexico

- Tecnológico de Monterrey has provided an institutional page with the option of requesting emergency medical, psychological, or nutritional care services for the entire university community.
- In a public university, the transition was made from face-to-face classes to distance learning through the institutional virtual platform and classes through Microsoft Teams.

Colombia

- The national government established a plan, so that the best-prepared universities in the modality of virtual distance classes would train the rest of the universities.
- Universidad Nacional de Colombia has established strategies for teaching and development of academic activities in a digital environment to reduce school dropouts.

Costa Rica

- University of Costa Rica has an IT Management Committee that meets four (4) times a year to make strategic decisions about the implementation of technologies in the institution. Among its digital transformation projects is the deployment of the virtual mediation platform for online courses and videoconferences via BigBlueButton, it also has a computational academic cloud with services such as a virtual laboratory for teachers and students, and teachers are also provided with a software kit so they can develop their multimedia content (Garrido, 2020).
- In the case of a public university with distance modality, the change became effective in the way of conducting tours, exams, laboratories, and delivery of

projects. These activities were adapted to be carried out virtually on the institution's Moodle platform with the complement of synchronous activities using tools such as Webex, Microsoft Teams, Zoom, and BigBlueButton.

Ecuador

- In a private bimodal university (face-to-face and remotely), the entire student community was transitioned to receive virtual classes through Zoom on a daily basis.

Uruguay

- In a public university, the decision was made for teaching to continue on digital platforms, adapting the evaluation process to this modality. Connectivity and equipment acquisition grants were established.

Venezuela

- In the case of a public university, the transition to the distance modality was led by the "Home University Plan" promoted by the national government through weekly videos on Television (TV) and the Internet (social networks) to guide students and teachers in this process.

Other alternatives to which Latin American universities have used include alliances with virtual platforms specialized in massive and open online courses or massive open online course (MOOCs) such as Coursera (Times Higher Education, 2020) and Edx (Galileo Universidad, 2020), allowing students to access educational content without the need for the institution to go through the complicated content production process, but validating that the material is relevant to the curriculum of each academic program offered. Partnerships with universities from other continents have also emerged to offer virtual master's programs, as is the case of IICA (Instituto Interamericano de Cooperación para la Agricultura)—Spain (BioEconomía, 2021) and Panama—Portugal (Facultad de Ingeniería de Sistemas Computacionales, 2021), seeking to break the barriers of face-to-face education for formal technological training through university internationalization.

In the field of distance education, more and more students are interested in participating in both accredited and non-accredited online courses, which show a tenfold increase in the participation of these courses than in the previous decade in the Latin American region, fostering the emergence of fully digital universities such as the Brazilian *Descomplica* and online certification platforms such as *Platzi* (Atlantico, 2020).

5 Digital Transformation in Some Central American Universities

In order to have an overview of the level of digital transformation of Latin American universities, an instrument was applied to Central American universities, of which 20 responses were obtained from universities in Panama, Costa Rica, El Salvador, Nicaragua, Honduras, and Guatemala. To comply with data privacy requirements, the survey remains anonymous and not personally identifiable or confidential data is collected from participants.

5.1 Survey Methodology

With the concept of digital transformation as the process of migrating the organization from a traditional approach to new ways of working and thinking, incorporating emerging technology, as well as promoting leadership, stimulating innovation and digitizing processes, the survey includes five parts, namely (Marks et al., 2020):

- Teaching and learning processes
- Student support processes
- Research processes
- Administrative processes
- Open questions

Based on these five aspects, a pilot survey with eight questions was applied (Table 1). A range was selected within the Likert scale (from 1 to 5), 1 being the

Table 1 Survey questions

Survey question (Spanish original version)		Measure
1	Indicate the type of institution of higher education	Control
2	Indicate the region where your institution is located	Control
3	Teaching and learning processes	Likert scale
4	Student support processes	Likert scale
5	Research processes	Likert scale
6	Administrative processes	Likert scale
7	How has your organization implemented digital transformation in strategic management, culture, leadership, and communication processes?	Open
8	Which projects is carrying out your institution?	Open

lowest and 5 the highest, based on the criteria described, according to the level of technological innovations implemented. To maintain data privacy, each surveyed university was assigned a code in such a way that they could openly express the situation that exists in terms of technological transformation in their universities.

5.2 *Survey Results*

The purpose is to know, from the institutional perspective, the level of digital transformation of the universities in the Latin American region.

5.2.1 General Information

Institutions were classified according to their way of operation, public or private, with the premise that there may be a relationship between the level and speed of digital transformation and the way of operation and financing of the institutions. Regarding this aspect, half of the surveys were answered by private institutions and the other half by public institutions (Fig. 1).

Considering that 50% of public universities and 50% of private universities that responded this survey, we want to analyze question 2. An important point in the digital transformation is to invest in talent, skills, and knowledge of people. What projects is your institution carrying out or expects to carry out? since digital transformation requires investment.

Both public and private universities refer to the fact that they are training, updating, and promoting their human resources, some of the private universities speak of projects of hiring trained human resources, and expansion of software for its application in teaching and administrative processes. Other universities have invested

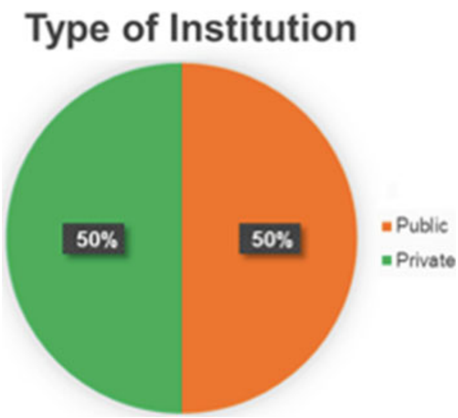

Fig. 1 Type of institution in the study

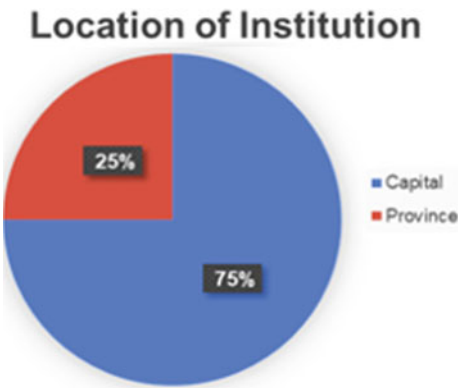

Fig. 2 Location of each institution in the study

in projects to digitize processes, some public universities say that some projects currently in demand were not included in their budget plans.

Public universities obtain a greater part of the state budget, all their money disbursement processes are supervised by government entities, and this becomes a disadvantage when carrying out activities that require budgetary investment, due to government controls, while in the case of private universities, they are making use of their investment processes without the need for such rigorous government controls, thus allowing them to have a more immediate response to the investments that are demanded.

On the other hand, it was considered to know the location of the institutions, if they are from the capital of the country or a province, since this aspect can influence the speed of implementation of digital transformation. Figure 2 shows that the majority of 75% of the responses were from institutions located on capital cities.

5.2.2 Digital Transformation on Teaching and Learning Processes

In the first section, the level of digital transformation of aspects related to academic subjects of the university was evaluated, namely: accreditation of study programs, teaching processes (preparation and development), evaluation of teaching processes, and mobility of student and teachers.

The highest results of the survey are presented in the teaching processes, which shows that the universities have ventured into the transformation mainly of the teaching processes (preparation, development, and evaluation) (Fig. 3).

5.2.3 Digital Transformation on Student Support Processes

In this section, the level of digital transformation on aspects related to the services offered by the university to students was evaluated, according to the level of technological innovations implemented in: student management services, library and

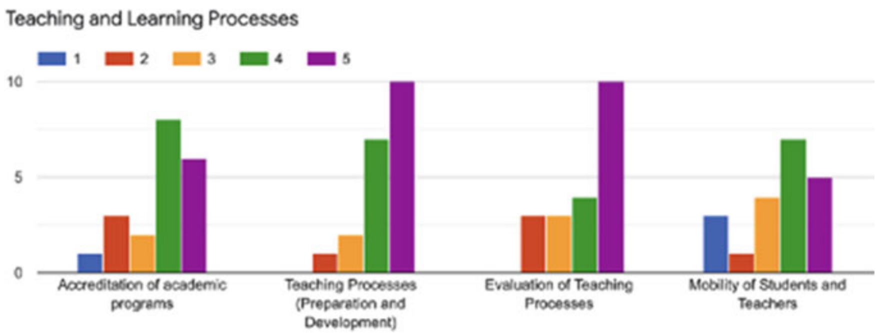

Fig. 3 Teaching and learning processes

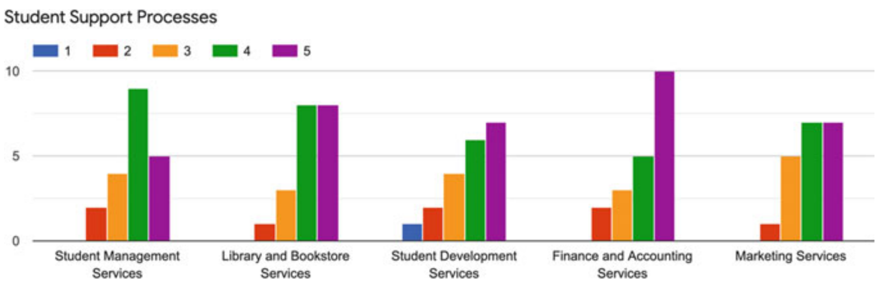

Fig. 4 Student support processes

bookstore, student development, financial and accounting services, and marketing services.

In this aspect, it is noted in Fig. 4 that there have been efforts in the implementation of technological innovations mainly in library and bookstore services, as well as in financial and accounting services, which makes sense as many universities have provided economic support for students such as loans, discounts, among others.

5.2.4 Digital Transformation on Research Processes

In this section, the level of digital transformation of aspects related to the development, and promotion of the research was evaluated, particularly in research planning, research preparation, follow-up during the execution of research, monitoring of research results, and evaluation of research.

In Fig. 5, the results show a high level in the implementation of innovations in all the processes related to the development and support of research activities in the universities.

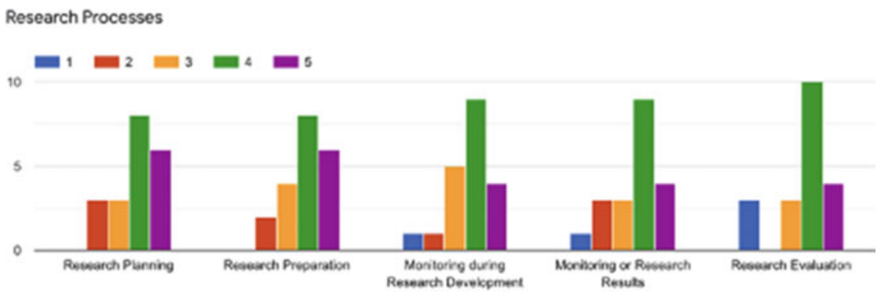

Fig. 5 Research processes

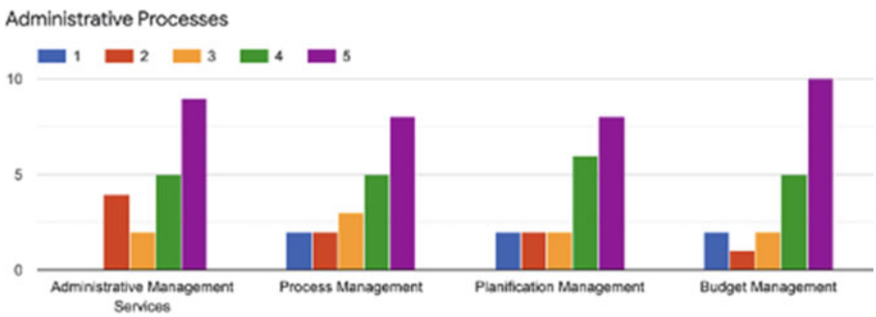

Fig. 6 Administrative and planning processes

5.2.5 Digital Transformation on Administrative Processes

In this section, the level of digital transformation of aspects related mostly to administrative and planning processes was evaluated according to the level of technological innovations implemented in terms of administrative management services, process management, planning management, and budget management. The results are shown in Fig. 6.

5.2.6 Open Questions

Table 2 presents some statements from the members of the universities that participate in this study, regarding how their institutions have implemented digital transformation in administrative, culture, leadership, and communication aspects.

An important point in digital transformation is investing in people's talent, skills, and knowledge. Table 3 shows the responses given by the respondents regarding projects that the institution is carrying out or plans to carry out to address this aspect.

Table 2 Organization of digital transformation in administration, culture, leadership, and communication processes

Country	Universities	How has your organization implemented digital transformation in strategic management, culture, leadership, and communication processes?
Panama	TDUNI001	It has built the first phases of a virtual community where teachers, students, and staff interact within an annual operational plan as a result of a strategic plan
	TDUNI002	Standard classes with mandatory training were organized for all teaching and administrative staff. Large amounts of money were invested in technology. Regular, continuous meetings were organized according to areas and roles. The use of networks was expanded, and communication with students and teachers was increased. The university has implemented the Attention and Service Center (CAS) to easy and streamline all administration and communication processes
	TDUNI003	Developing and training human resources, reviewing institutional policies, implementing regulations, and investing in the acquisition of technological resources and development of new software applications
	TDUNI004	Through the selection of platforms and their progressive application in various processes
	TDUNI005	Through staff training
	TDUNI006	The University works under the ISO 9001-2015 Standards, which has clearly established policies and procedures for each of the processes it carries out. In accordance with the above, the entire staff has adapted the inherent activities in accordance with the demands of virtuality. Teleworking has been implemented with the use of all available tools to ensure compliance with the university plan
Guatemala	TDUNI007	The transformation has not only been to create digital products and services and has a Web site or profiles on social networks. The change has been aimed at strengthening the main operations within the university through the adoption of new technologies and methodologies. There is an important change in the way that collaborators carry out activities, as well as in their behaviors and the way in which they interact with others inside and outside the university
	TDUNI008	Implementation in the use of social media for institutional delivery of their accomplishments and information for the university community, organizational culture based on new trends in telework, online classes, among others, for the benefit of users, students, teachers, and administrative staff
Nicaragua	TDUNI009	Planning processes have been developed and progress that has been made in main areas of the university, developing and creating new cultures of virtualization through MOOC courses and virtualization of the academic curriculum

(continued)

Table 2 (continued)

Country	Universities	How has your organization implemented digital transformation in strategic management, culture, leadership, and communication processes?
	TDUNI010	Policy creation, budget resource allocation, development of digital technologies, process automation, and continuous comprehensive training in all areas
El Salvador	TDUNI011	Digital transformation has been developed since 2016 with quality standards, new online and distance training offers have been opened, teaching training in the use of computer applications. In the face of the COVID pandemic, the digitalization and virtual attention processes have been improved in academic settings. Before 2020, very few teachers and administrative staff used their institutional email, by using communication platforms and promoting processes interconnection, the use of virtual communication channels, and mail increased. The administration and finance processes still have many weaknesses that prevent promoting digital transformation, access to technology is not entirely the problem, but cultural. Many internal management processes are still manual, very few units have information systems on platforms, and access to information in real time is non-existent. There is no digital signature since it is not accepted at the national level
Costa Rica	TDUNI012	The university has implemented practically all its processes digitally, and strategic management is carried out through protocols, agreements, regulations, and virtual meetings
	TDUNI013	The changes generated have been basic and designed thinking on the face-to-face return, at the administrative level. No substantial improvements have been implemented in the teaching processes
Honduras	TDUNI014	Training, technology acquisition, consulting, and constant evaluation

6 Experience of Universidad Tecnológica De Panamá in Its Digital Transformation: Institutional Perspective

Universidad Tecnológica de Panama (UTP) was created in August 1981, dedicated to engineering, sciences, and technology, in an integral way and at the highest academic level. It is a public institution whose main campus is located in Panama City, Republic of Panama, and has a nationwide presence with seven regional centers. Currently, 143 careers are offered at different levels, with a teaching staff of 1773 teachers and an enrollment of 24,204 students in 2020.

With a vision toward a digital transformation approach, several initiatives have been undertaken by UTP. The UTP 2030 Route has been defined, together with a strategic planning model, based on a management focused on the transformational leadership model, through which the organization and its members grow. The Institutional Development Plan (PDI) 2018–2030 (Universidad Tecnológica de Panamá, 2018) has five development areas: (1) Teaching, (2) Research, (3) Innovation and Linkage with Society, (4) Internationalization, and (5) Management, in each of which

Table 3 Projects carried out by university

Country	Universities	Which projects is carrying out your institution?
Panama	TDUNI001	We are in the process of consolidating a virtual community in which main university segments have participated in a duly planned training program in virtual environments. The program is part of one of the projects of the five-year Strategic Plan of the university
	TDUNI002	A special commission has been kept developing different types of abilities, skills, and increased the content to be shared
	TDUNI003	The institutional policy is to invest in human talent, and this is achieved through training, attendance at conferences, workshops, congresses, participating in scientific and research meetings, stimulating and promoting the participation of human resources in these activities
	TDUNI004	Training in software for its application in teaching and administrative management
	TDUNI005	Process digitization
	TDUNI006	A permanent training program is being developed for staff involved in administrative and teaching activities. Seminars, conferences, and workshops have been given, and permanent supervision has been carried out to accompany and monitor the staff
Guatemala	TDUNI007	Extremely important we have continuous training with teachers and researchers as well as in the administrative area
	TDUNI008	Implementation of MOOC courses for the development of soft and hard skills
Nicaragua	TDUNI009	With the 20–30 Strategic Plan of the university, human talent is one of the main updating strategies in the virtualization process of the teaching staff
	TDUNI010	Continuous comprehensive training in all areas
El Salvador	TDUNI011	The Vice-Rector's Office has a teacher training plan, and efforts are being made to update computer skills and abilities and digital transformation, but it was not incorporated into financial planning, although for more than 10 years the University Development Plan has already established a bet on this field of action
Costa Rica	TDUNI012	Courses and trainings have been offered virtually, and distance and virtual training is promoted for staff and students
	TDUNI013	An improvement in the university's technological platform is expected
Honduras	TDUNI014	Teacher training in digital teaching skills, training in the use of teaching and learning platforms and mechanisms

work has been done on the TD process. Table 4 presents a summary of the strategies implemented to date.

Authors (García-Peñalvo & Corell, 2020), after preliminary evaluating the impact of COVID-19 in higher education institutions, have evidenced the need for continuous evaluation. UTP, maintaining quality controls in the sudden implementation of distance education, carried out a series of follow-up surveys to teachers and students

Table 4 Summary of actions

Area of development (PDI)	Strategy implemented	Description
Teaching	Updating the Learning Management System (LMS)	LMS update used: Moodle and use of Office 365 tools Training through inductions, preparation of guides, videos and tutorials of use of platforms aimed at students and teachers. They are for internal use only for members of the UTP community
	Re-activation of the International Center for Technological Development and Free Software (CIDETYS)	It is an association of public interest in order to promote projects of general interest in the scientific, technological, educational, and economic field related to information and communication technologies, facilitating the access of different agents, whether public or private to technological development and to benefit from the use, development, dissemination of the advantages, and freedoms of free software For details: https://www.cidetys.org.pa/
	The Digital Resources (RD) platform	It is a platform designed so that the entire UTP community has access to different digital resources (webinars, podcasts, tools, programs, and others), as a complement to support remote and virtual education https://recursosdigitales.utp.ac.pa/
	Admission Test	It employs the use of existing tools on our servers such as email, Moodle, and Microsoft Teams, to perform the tests in a virtual way It is for internal use by the university

(continued)

Table 4 (continued)

Area of development (PDI)	Strategy implemented	Description
Research	Institutional repository of open access digital documents of the Technological University of Panama (UTP-RIDDA2)	It is a set of centralized Web services, created to organize, manage, preserve, standardize, and offer free access to scientific, academic, or other cultural production, in digital format, generated by UTP members who are in Panama or outside our territory For details: https://ridda2.utp.ac.pa/que-es-utp-ridda2
	Scientific Information System of the Universidad Tecnologica de Panama (SicUTP)	It is a platform that allows to have a structured and up-to-date database for researchers of the Universidad Tecnologica de Panama For details: http://www.investigadores.utp.ac.pa/
Innovation and linkage with society	Continuing Education Management System (SIGEC)	It is a tool to facilitate the consolidation and control of all the activities carried out by the Universidad Tecnologica de Panama in the field of continuing education It is for internal use by the university
Internationalization	TIC Cruz del Sur ICT Platform for International Mobility Management	It is a tool, and the product of an Erasmus + CBHE international project with the University of Murcia in which the platform was developed based on the requirements of Latin American universities members of the consortium. The tool seeks to streamline and standardize international mobility processes, as well as carry statistics For details: https://ticcruzdelsur.um.es/ticcruzdelsur/utp/movilidad.publico.index.do

(continued)

Table 4 (continued)

Area of development (PDI)	Strategy implemented	Description
Management	The Electronic Clinical Records System (SEE-UTP)	It is a platform that seeks to streamline health care processes for the university community, increasing the number of daily care and extending quality primary care services to UTP Regional Centers and Extensions. It will allow future analysis of the recorded data, to carry out projections and studies that impact the university community It is for internal use by the university
	Electronic platforms for tuition and academic services	Tools to facilitate payments by electronic means to all students at the national level It is for internal use by the university
	2018–2030 POI Tracking Web Platform	Working platform that provides up-to-date information on the achievement of the goals defined in each area of institutional development. Utilizes business intelligence tools It is for internal use of the university: http://pdi.utp.ac.pa
	Digital Platform Institutional Assessment and Accreditation Process Hcéres-UTP	Digital platform for the first process of Evaluation and Institutional Accreditation Hcéres in virtual mode. The platform contains all the evidence and was used to support the external peer evaluation process It is for internal use of the university: https://hceres.utp.ac.pa/

in 2020, with general positive results. In the future, the implementation of artificial intelligence is projected to different processes within the UTP and also to the educational evaluation processes, taking as a reference experiences from other universities in the Latin American region (Flegl et al., 2017; Gutiérrez et al., 2018). Also, by the program Digital Evolution Education Program (DEEP), within the framework of the Technological Frontiers Initiative (TFI) of LASPAU (Harvard University), a training is given for ten teachers and researchers to support this implementation and accelerate the adoption of technology in the higher education institutions in Latin America.

7 Discussion and Conclusion

Currently, the world is in a digital transformation as a result of the health crisis of COVID-19 and as the universities of Central America are facing this situation, to continue providing their services, it is a challenge for their digital transformation, considering the adaptation of all face-to-face processes in virtual environments and remote modalities. Some Latin American universities are making efforts to carry out digital transformation in administration, culture, leadership, and communication processes. These processes have had a direct impact on the way of carrying out the teaching–learning process, although it is true at the beginning of the pandemic, the educational system at the higher level proposed different alternatives and methodologies to face this situation; however, nowadays, through the results obtained in the applied surveys, it is evident how tools, platforms, and systems have been implemented promptly, mainly to support the teaching and learning process, and also for the administration, culture, leadership, communication, and management processes, the efforts of a readjustment have been eminent to be able to offer all or the main processes demanded by the university community in general.

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Behavior Analysis of Digital Transformation in Latin American and Colombian Universities, Based on a General Identification of Variables

Lina María Castro Benavides, Johnny Alexander Tamayo Arias, and Daniel Burgos

Abstract As a consequence of the Industrial Revolution 4.0, many organizations have been forced to initiate digital transformation processes in order to survive in a new context that demands dynamic and flexible responses from them in a very short time. Consequently, universities are not oblivious to this change and therefore are on the road toward accomplishing it. This chapter explores the digital transformation processes that have been used by Latin American universities and specifically public universities in Colombia, demonstrating that this complex task has manifested itself from different perspectives, such as social, organizational, and technological. At this point, it is important to identify the variables in such processes and how these changes have been developed. Firstly, the concept of digital transformation is explained from the universities' point of view. Secondly, the different processes of digital transformation extracted from the documents reviewed are consolidated. Finally, the variables that are part of digital transformation processes are identified.

Keywords Digital transformation · Digital university · Digital processes · Digital implementation · Latin American universities

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1 Digital Transformation Context

Digital transformation has become a priority for higher education institutions (HEI) in this second decade of the twenty-first century, given that this is a natural and necessary process for organizations that claim to be leaders of change and to be highly competitive in their domain (Benavides et al., 2020). In the most general context, it is increasingly viewed as an imperative and has led organizations to rethink how they can use technology to improve their performance or expand their business. Hence, companies need to think of digital transformation as a "formal effort to renovate business vision, models, and investments for a new digital economy" (Solis et al., 2014). As a consequence, it requires changes and the involvement of people, processes, strategies, structures, and competitive dynamics (Wade, 2015) through organizational adjustments based on the use and convergence of several resources and advances of emerging technologies, such as big data, cloud computing, artificial intelligence, augmented and virtual reality, mobile apps, social media, the Internet of things, and blockchains, among others (Rodrigues, 2017). In this sense, two different but interdependent developments can be identified: on the one hand, innovations in digital technologies drive the need for transformation and adaption in organizations, but on the other hand, digital innovation is also shaped by the changing demands and requirements of users implementing these innovations. Thus, to understand the impact, it is necessary to address both sides of digital transformation: new technologies and tools as well as changing user requirements through digital innovations (Bresinsky & Von Reusner, 2018). All this new investment in technology and business models to more effectively engage digital customers at every touchpoint in the customer experience lifecycle must be a realignment (Solis et al., 2014). Abad-Segura et al. (2020, citing Shrivastava) reported that it has been recognized that a digital transformation must be established according to the axioms of connectivism to unify its commitment to meeting the expectations of the different interest groups in the economic, social, and environmental dimensions.

Regarding the impact of digital transformation in the context of HEIs, it could be stated that avoiding digital transformation is not an option, times of crisis cause changes in institutions that tend to move more slowly (Ramírez Montoya, 2020), and HEIs are required to adapt to technological changes if they want to stay relevant. In this sense, implementing new technologies is inevitable, and it becomes a real challenge which demands correct execution of the available digital plans and strategies, engaging and empowering students, staff, and faculty in the process (Abad-Segura et al., 2020). A digital transformation is both desirable and indispensable, but it is also a facilitator of professionalizing the management of the university, opening new opportunities to expand customer reach (new customer segments) and the customer experience (customer relationships) (Bond et al., 2018). Stolze et al. (2018) expressed that a major challenge faced is how to adopt and leverage new digital technologies, as the ability to promote digital transformation is in large part determined by a clear digital strategy enabled by a culture of change, risk-taking, and innovation, supported by its leaders, including prerequisites, internal changes, and expected outcomes (Mergel et al., 2019).

Additionally, Abad-Segura et al. (2020) expressed that the constant emergence of new digital technologies creates both challenges and opportunities to change the functioning of HEIs, both internally (e.g., virtual campus) and externally (e.g., social networks), likely evidencing a gap in resources and capabilities to manage this digital transition and generating tensions which must be overcome if HEIs are to make the right decisions to survive and thrive in the future. Mergel et al. (2019) noted that the demands for digital transformation in public administration are mostly driven by external rather than internal demands, through changes observed in the organizations' environment, technology, and requests made by stakeholders. In this sense, digital transformation of the university education system should have a broader focus and has to include the modernization of corporate IT architecture management, which could provide an important contribution to structuring the efforts of innovation in education (Kaminskyi et al., 2018).

In the public sector context, Mergel et al. (2019) considered that digital transformation approaches outside this sector are changing citizens' expectations of public administrations' need to deliver high-value, real-time digital services. For Mergel et al. (2019), digital transformation in the public sector means new ways of working with stakeholders, building new frameworks of service delivery, and creating new forms of relationships. Bond et al. (2018) considered that the main solution seems to be an increased professionalization and organizational digital readiness at different levels (skills, capabilities, tools, guidelines, and so on). Therefore, based on the current trends, it is clear that the formation of human capital is necessary in all areas of the digital economy, and the university must act as a highly effective tool in the development of human capital to achieve a new quality of life in the country (Bagdasarian et al., 2020). Subsequently, it is especially important to focus on new technologies in the educational paradigm in the digital economy conditions, taking into account new trends in the labor market. Meijer and Bekkers (2015) expressed that technology enactment is the result of cognitive, cultural, structural, and political embeddedness. As a result of this embeddedness, the change that occurs must deal with the influence of specific socio-structural mechanisms (like existing rules, routines, norms, and power relations) that are present in specific organizational and institutional arrangements.

In the pandemic context, BID (2020) considered that the accelerated form of adoption of digital transformation universities that were moving toward was necessary because of the social distancing measures imposed by the pandemic. Among the advantages identified in the adaptation process of some universities are that the educational model of the university influences its ability to react. Additionally, universities that had begun a transition to digitization before the pandemic and had a technological infrastructure already had some experience in the development of a digital culture, with students and professors more adapted to mechanisms such as digitized procedures and face-to-face courses taught in a hybrid format with online curriculum content. Moreover, there was a financial investment in resources for educational continuity and reduction of the digital divide, as well as the continuing education for teachers. On the other side, facilitating remote work for the university's administrative staff realized the institutional strength; when there is a strong relationship between deans, professors, and the university administration, and ideals are shared and there are no power struggles, it is possible to mobilize the university in a virtual way and a face-to-face way. However, there is a risk that the process will fail due to the accelerated form of adoption, without enough time to train the actors involved or generate a sustainable technological capacity. Government teams must be aware of the importance of this transformation and create leadership over the new university paradigm, considering that technologies must be incorporated into university strategic plans, not as a support to the institution, but as an extension of the pedagogical strategy.

1.1 Latin American Universities Context

Some studies have been carried out in the Latin American context. For instance, the IDC InfoDoc (2019) assessed the level of maturity of Latin American universities in the context of digital transformation, indicating that four out of ten institutions were digital resistant (companies without objectives or a structure around digital transformation initiatives) and preferred to continue with the traditional system of teaching; almost a third were digital explorers (companies that have occasionally experienced digital transformation projects), where some areas or campuses had begun to use some of the functionalities of blended learning platforms; and only 2.4% of the universities positioned themselves as digital disruptors (highly disruptive companies in terms of the use of technology and new business models), which were innovating their teaching–learning processes throughout the school. A similar situation faces the administrative part of higher education institutions on a sensitive issue for schools, countries, and the entire region in general: the high student dropout rates, derived mainly from the deficiencies of their previous educational training, a lack of economic resources, or the social or family environment. Based on the responses from the universities participating in this blended learning study, institutions are making slow progress, since 43% of them were "digital resistant," as they had the tools but made isolated use of them. For this reason, they had low technological use and continued to concentrate on the teaching–learning process in the classroom. At the highest level, disruptors were only 2.4% of the sample. These are innovative universities that went further in the standard use of each technology by exploring new capabilities or uses within teaching–learning processes, such as the integration of augmented reality in virtual laboratories.

Padilla-Verdugo and Saquicela-Galarza (2020) proposed a governance model of information technologies based on the COBIT 5 processes for the University of Cuenca, Ecuador, which involved important changes in the role that technology plays in organizations, the prioritization of their strategies and governance components, the work model, governance and management structures, processes, and corporate culture management.

Lamelas and Belli (2018) analyzed the uses of digital technologies by the academic community in Latin America, along with their functions, limitations, and potentialities. With the purpose of building a common framework that allowed for the mediation of technologies in the production of knowledge and the development of equitable collaborative networks, they analyzed 18 interviews with researchers from Latin American technical universities and performed a thematic content analysis. The authors evidenced that digital technologies act as necessary infrastructure for (a) the creation of networks between professionals and institutions to overcome material difficulties, (b) the search for and accumulation of information, (c) the production of knowledge and the improvement of competitive capacity, and (d) the dissemination and increase of the visibility of research results.

Additionally, Ramírez Montoya (2020) analyzed the contingency responses of digital transformation and pending subjects of educational innovation in the university environments of Latin America. The methodology applied was a multiple-case study with an instrumental approach. The findings addressed the challenges of digital transformation (virtualization, training, infrastructure, connectivity, culture, management, and open education) and educational innovation (new processes, products, services, knowledge, and research).

Arango Serna et al. (2019) presented a case study of Universidad Nacional de Colombia, which carried out its initial phase of digital transformation through divulgation with the members of the top management of the university and prioritized its intervention in two aspects: first, the generation of the organizational culture around the digital transformation, and second, the creation of the institutional strategic project "Transformación Digital U.N. 2030."

Studies around digital transformation in Latin American universities have shown, on the one hand, a general background of their current state, and on the other, specific projects for the application of digital transformation processes within universities. This study presents a statistical analysis, using multiple correspondence analysis that shows the relationship and importance of the implementation of digital transformation as an organizational transformation that must be carried out in a holistic way, considering the organizational, social, and technological perspectives.

Universities must prepare to respond to the current and future requirements of a digital globe. Based on this discussion of the literature, it is important to know the Latin American scenario. Therefore, the following sections presents the methodology, followed by the research and its results, discussion, and conclusions.

2 Methodology

This research followed four steps (Fig. 1) required to be a complete, objective, and reliable overview.

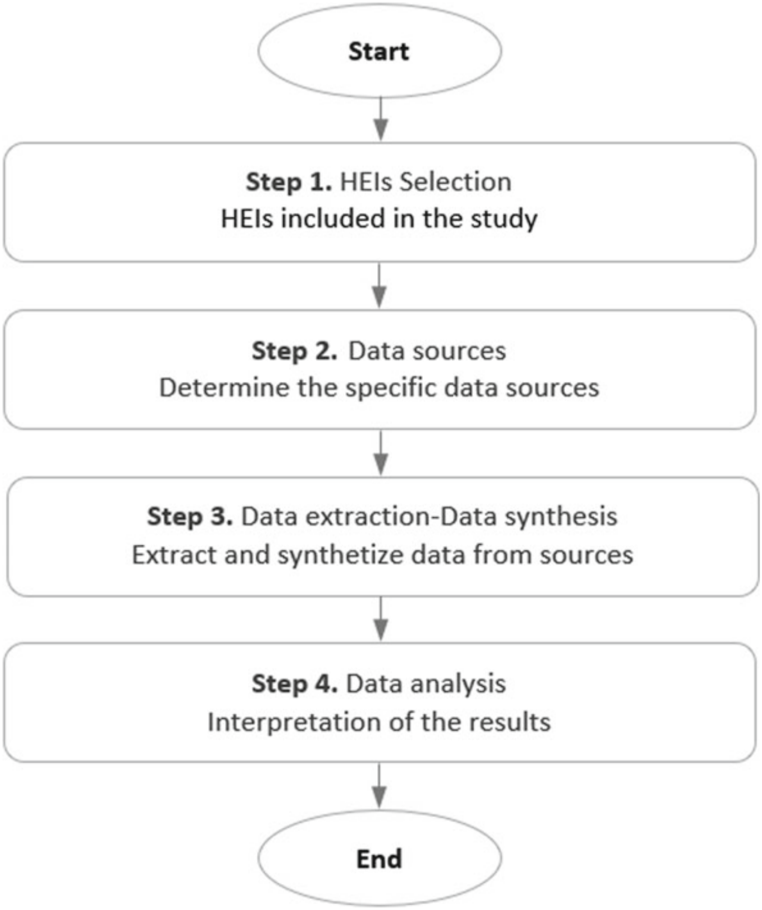


Fig. 1 Methodology—flow diagram

2.1 Universities Selection

2.1.1 Latin America Selection

The Latin America study focuses on the research results obtained by Ramírez Montoya (2020) in the study "Digital Transformation and Educational Innovation in Latin America Within the Framework of Covid-19." It used a multiple case study methodology with an instrumental approach, with descriptive and categorical analyses in Argentina, Chile, Colombia, Costa Rica, Ecuador, Mexico, Peru, the Dominican Republic, Uruguay, and Venezuela. The digital transformation responses and pending educational innovation subjects were analyzed in Latin American university environments.

2.1.2 Colombian Study Selection

In Colombia, there are 85 universities, including both private and public institutions. The Colombian study focuses on the 32 Colombian universities that are public.

2.2 Universities Data Source

2.2.1 Latin America Data Source

To carry out the study, the article "Digital Transformation and Educational Innovation in Latin America Within the Framework of Covid-19" was considered (Ramírez Montoya, 2020).

2.2.2 Colombian Public Universities Data Sources

To carry out the study, three data sources were considered:

1. The database of public universities provided by the SNIES platform belonging to the Ministry of National Education of Colombia. The original database provides the following fields: University Code (numeric), University Name (alphabetic), and High-Quality Accreditation (categorical).
2. The Strategic and Development Plans that each university published on its Web site, in compliance with Colombia's Law of Transparency and the Right of Access to Public Information (Law 1712, 2014).
3. Internet search (Google search engine) of the digital transformation activities that each university had officially published. The structure used to realize the search of the articles was "digital transformation" + "university's name," and the search was conducted between October 1 and October 30, 2020.

2.3 Data Extraction

The information from data sources was analyzed and classified as follows:

- Design of Data Extraction Forms

  Microsoft Excel was the software used to manage the data.

- Data Extraction Procedures

  This data collection process was developed in three stages.

  Information Analysis: The analysis and classification of the information considered the suggestions of Benavides et al. (2020), following a bottom-up analysis.

Table 1 Acronyms to classify information

Perspective	Acronym
Organizational digital transformation	GOV-DT business government
Social digital transformation	VI-virtual, CAP-capacitation, INF-information, CUL-digital transformation culture, MOD-educative models
Technology digital transformation	PLV-virtual platform, INF-SI infrastructure, SI-information systems, PLA-digital platforms, TIGOV-TI government, CENT-multimedia center

Classification of Information: According to the information analyzed from the data sources, Table 1 shows the considered acronyms for the information analysis.
Information Extraction: The information was classified according to the codes established in the classification of information analysis step.

2.4 Data Synthesis

A new Excel sheet was created to synthesize and organize the information collected from the documents in the required format for its subsequent analysis. Table 2 shows the columns created.

2.5 Data Analysis

This step was carried out in two stages. Firstly, a multivariate statistical technique was applied to obtain a data reduction or structural simplification, as expressed by Johnson and Wichern (2007), with the purpose of studying the phenomenon represented as simply as possible without sacrificing valuable information. Moreover, to analyze categorical variables, the appropriate multivariate technique is correspondence analysis (CA), and when the data table is a set of observations described by a set of nominal variables, CA becomes multiple correspondence analysis (MCA). In this sense, according to Hervé and Dominique (2007), each nominal variable comprises several levels, and each of these levels is coded as a binary variable. The complete data table is called a Burt matrix. Subsequently, the mathematical process behind MCA is required to calculate the measures of association. Lastly, the number of dimensions is assessed, and the perceptual map obtained is analyzed to interpret the results. Secondly, the analysis of the findings observed in the documentary review made it possible to describe the dimensions that have become more relevant in digital transformation at public universities in Colombia from the social, organizational, and technological perspectives.

Table 2 Dictionary data base

Column name	Description	Data type
HML DT	If the university has approached digital transformation processes from 3 perspectives (social, organizational, and technological), it is categorized as *high*; if from 2, it is categorized as *mid*; if from 1 perspective, it is categorized as *low* The formula used to classify the digital transformation process at public universities in Colombia was: = IF(COUNT.IF (D2:F2; "yes") = 3; "high"; IF (COUNT.IF (D2:F2; "yes") = 2; "mid"; "low"))	Categoric (high–mid–low)
Social DT	*yes*: when the university has carried out digital transformation processes from a social perspective *no*: otherwise	Categoric (yes–no)
Organizational DT	*yes*: when the university has carried out digital transformation processes from an organizational perspective *no*: otherwise	Categoric (yes–no)
Tech DT	*yes*: when the university has carried out digital transformation processes from a technological perspective *no*: otherwise	Categoric (yes–no)

In the next sections, we provide the synthesis of the results and the analysis of the study.

3 Results and Discussion

3.1 MCA Technique

3.1.1 Latin American Universities Results

After applying the necessary mathematics for the MCA, Tables 3 and 4 were obtained. The Burt matrix resulting from the consolidated database is shown in Table 3, and contribution to Chi square is described in Table 4.

Hair et al. (2009) indicated that an eigenvalue indicates the relative contribution of each dimension to an explanation of the inertia, or proportion of variation, in the participant and variable profiles. These eigenvalues can be interpreted as the correlation between the rows and columns of the contingency table, and those greater than 0.2 indicate that the dimension should be included in the analysis. In consequence,

Table 3 Burt matrix—Latin American universities

	HML DT	HML DT	Social DT	Organizational DT	Organizational DT	Tech DT
	High	Mid	Yes	No	Yes	Yes
HML DT high	1	0	1	0	1	1
HML DT mid	0	9	9	9	0	9
Social DT yes	1	9	10	9	1	10
Organizational DT no	0	9	9	9	0	9
Organizational DT yes	1	0	1	0	1	1
Tech DT no	0	0	5	6	0	0
Tech DT yes	1	9	10	9	1	10

Table 4 Contribution Chi square—Latin American universities

	Eigenvalue	Inertia	Chi-squared	%	% Cumulative
Axis 1	0.71	0.50	40	100%	100%
Axis 2	0.00	0.00	0.00	0.00%	100%

Table 6 consolidates the two axes created. The proportion of information in the model that is explained by each axis is given by the eigenvalues. The first axis explains the total inertia: the greater the dependence between variables, the greater the inertia. The first dimension explains 100% of the variance, and the second dimension explains 0.00%. This means that the categories present a greater variance dispersion on Axis 1.

Perceptual map: One of the results of the MCA technique is the perceptual map, which thanks to its display facilitates the understanding of the data insofar as the proximity or distance from the origin is analyzed, as well as the visualization of patterns and distribution along each axis. One of the characteristics of this map is that the origin becomes the centroid of each variable, which means that the closer a variable is to the origin, the closer it is to the average profile.

Now, it becomes necessary to introduce the nomenclature that has been used for the creation of the perceptual map and to explain it in detail.

- *Organizational DT_yes*: Universities that have approached digital transformation from an organizational perspective.
- *Organizational DT_no*: Universities that have not approached digital transformation from an organizational perspective.
- *Social DT_yes*: Universities that have approached digital transformation from a social perspective.
- *Social DT_no*: Universities that have not approached digital transformation from a social perspective.

- *Technological DT_yes*: Universities that have approached digital transformation from a technological perspective.
- *Technological DT_no*: Universities that have not approached digital transformation from a technological perspective.

Figure 2 illustrates the perceptual map, where Axis 1 is represented by the horizontal axis, and Axis 2, by the vertical axis. These two axes explain 100% of the data.

- HML DT_high and Organizational DT_yes are strongly associated. This means that the digital transformation processes of all the universities that have approached their digital transformation processes from an organizational perspective have been ranked "high."
- HML DT_mid, Social DT_yes, and Tech DT_yes are clustered together. This is the classification of digital transformation as "medium" due to the fact that the universities have approached it from the social and technological perspectives.

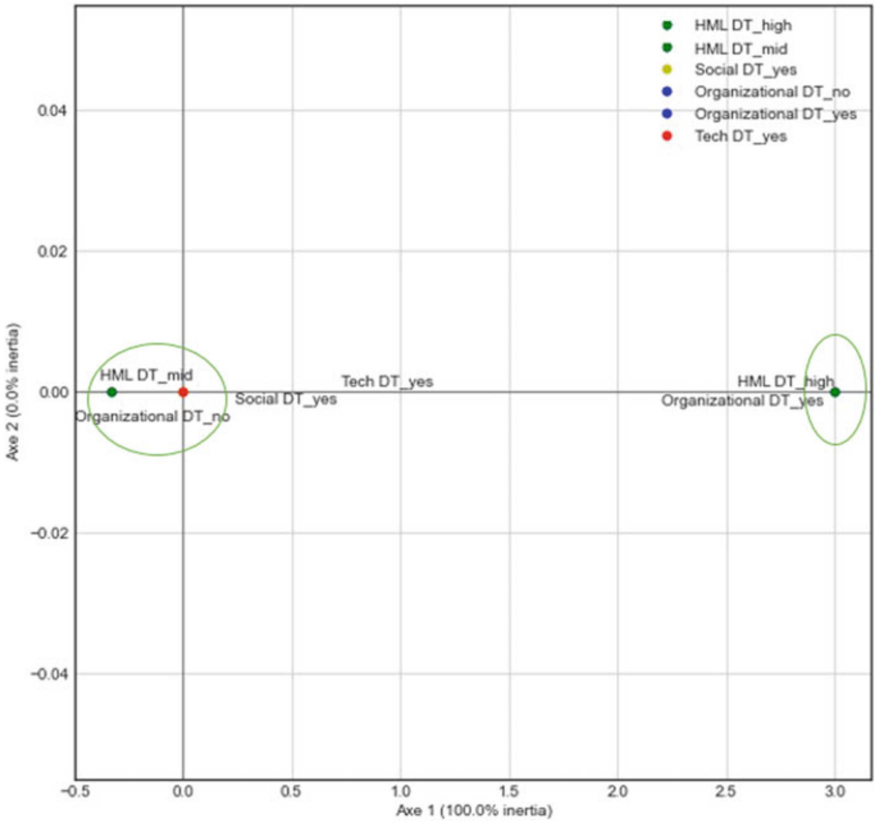


Fig. 2 Perceptual map—Latin American universities

- Finally, the farther categories are from the origin, the more discriminating they are. In that sense, it is highly differentiated that Organizational DT_yes and HML DT_high are the farthest categories; therefore, fewer universities have done digital transformation from an organizational perspective and are classified at a high digital transformation level (1 university). On the other hand, variables near the center are common in the data; as Social DT_yes and Tech DT_yes are the closest categories to the origin, it implies that many universities have carried out their digital transformation from social and technological perspectives (nine universities).

3.1.2 Colombian HEIs Results

After applying the mathematics required for the MCA, the Burt matrix resulting from the consolidated database is shown in Table 5, and contribution to Chi square is described in Table 6.

In Fig. 3, the first axis explains the 45.61% of the variance, and the second dimension explains 36.90%. This means that the categories present a greater variance dispersion on Axis 1, although both have a similar inertia value.

HML DT_high and Organizational DT_yes are strongly associated. This means that the digital transformation processes of all the universities that have approached their digital transformation processes from an organizational perspective have been ranked "high."

HML DT_mid, Social DT_yes, and Tech DT_yes are clustered together. That is, the classification of digital transformation as "medium" is due to the fact that the universities have approached it from the social and technological perspectives.

HML DT_low, Social DT_no, and Tech DT_no are clustered together. That is, the classification of digital transformation as "low" is highly related to the universities that have not approached it from the social and technological perspectives.

Finally, the farther categories are from the origin, the more discriminating they are. In that sense, it is highly differentiated that Organizational DT_yes and HML DT_high are the farthest categories; therefore, fewer universities have done digital transformation from an organizational perspective and are classified at a high digital transformation level (four universities). On the other hand, variables near the center are common in the data; as Social DT_yes is the closest category to the origin, it implies that many universities have carried out their digital transformation from a social perspective (30 universities).

3.2 Digital Transformation Processes

The different definitions of digital transformation (DT) may be categorized into three distinct elements: (1) Technological—digital transformation is based on the use of new digital technologies, such as social media, mobile, analytics, or embedded

Table 5 Burt matrix—Colombian public universities

	HML DT	HML DT	HML DT	Social DT	Social DT	Organizational DT	Organizational DT	Tech DT	Tech DT
	High	Low	Mid	No	Yes	No	Yes	No	Yes
HML DT high	4	0	0	0	4	0	4	0	4
HML DT low	0	7	0	2	5	7	0	6	1
HML DT mid	0	0	21	0	21	21	0	0	21
Social DT no	0	2	0	2	0	2	0	1	1
Social DT yes	4	5	21	0	30	26	4	5	25
Organizational DT no	0	7	21	2	26	28	0	6	22
Organizational DT yes	4	0	0	0	4	0	4	0	4
Tech DT no	0	6	0	1	5	6	0	6	0
Tech DT yes	4	1	21	1	25	22	4	0	26

Table 6 Contribution Chi square—Colombian public universities

	Eigenvalue	Inertia	Chi-squared	%	% Cumulative
Axis 1	0.76	0.57	135.67	45.61	45.61
Axis 2	0.68	0.46	109.74	36.90	82.51

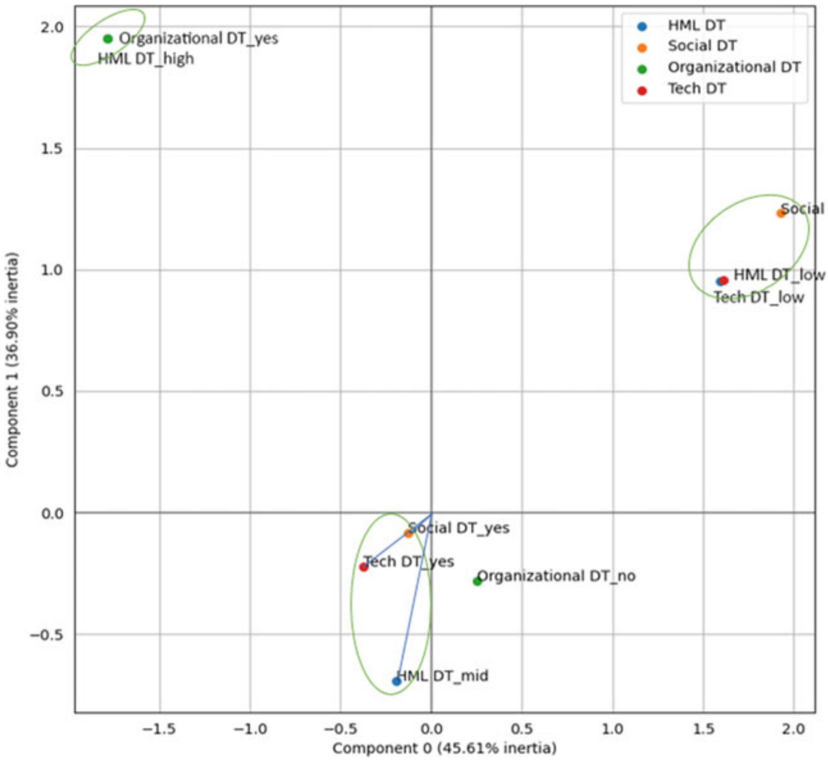


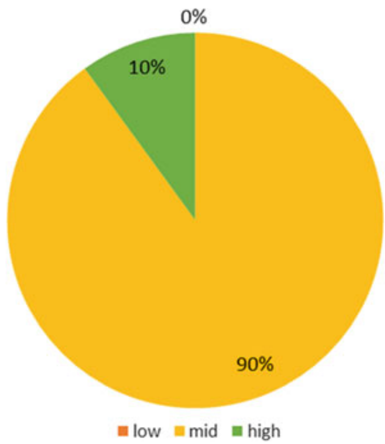
Fig. 3 Perceptual map—Colombian public universities

devices; (2) Organizational—digital transformation requires a change of organizational processes or the creation of new business models; (3) Social—digital transformation is a phenomenon that influences all aspects of human life by, e.g., enhancing customers' experience.

3.2.1 Latin American Universities' Digital Transformation Processes

In Fig. 4, it can be seen that 90% of Latin American universities (nine universities) have a digital transformation classified as medium, while the remaining 10% (one university) has been classified as high.

Fig. 4 Digital transformation—Latin American universities



In Fig. 5, it can be observed that 100% of Latin American universities (ten universities) have executed digital transformation processes from the social perspective.

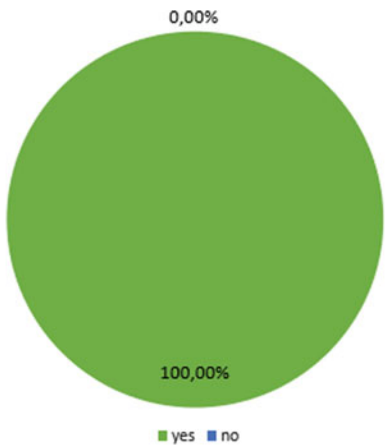
Figure 6 shows that 90% of Latin American universities (ten universities) have not executed digital transformation processes from the organizational perspective, while 10% (one university) evidence digital transformation from this perspective.

Figure 7 illustrates that 100% of Latin American universities (ten universities) have executed digital transformation processes from the technological perspective.

Taking into account the dimensions considered by Benavides et al. (2020) and contrasting them with the data collected, Fig. 8 was obtained; it shows the digital transformation dimensions radar applied to the Latin America universities.

Figure 8 indicates that universities have prioritized the dimensions of teaching, human resources, and infrastructure (ten universities). Next, seven universities have

Fig. 5 Social perspective of digital transformation—Latin American universities



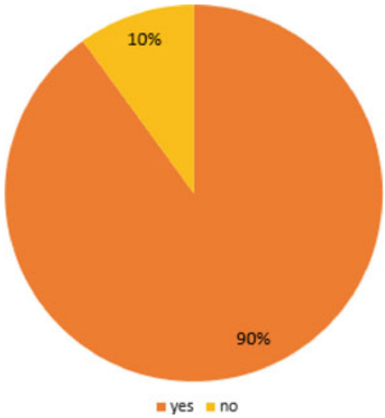


Fig. 6 Organizational perspective of digital transformation—Latin American universities

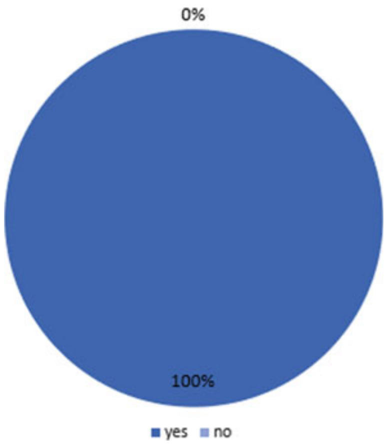


Fig. 7 Technological perspective of digital transformation—Latin American universities

considered the dimension of curriculum. After that, six universities have considered the information dimension. One university has studied the business process, administration, and extension dimensions, and none have delved into research or marketing.

3.2.2 Colombian Universities' Digital Transformation Processes

The following graph (Fig. 9) shows the classification of universities according to their level of adoption of the digital transformation.

Figure 9 shows that 66% of the public universities in Colombia have carried out internal digital transformation processes from two perspectives (social, technological, or organizational). Further, 22% of public universities in Colombia have carried out internal digital transformation processes only from one perspective, be it social,

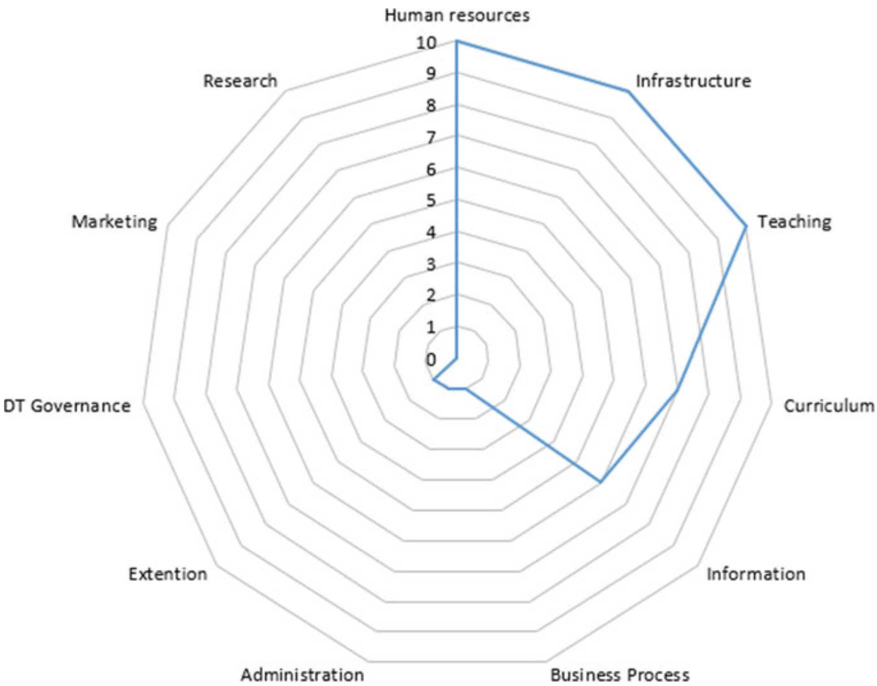
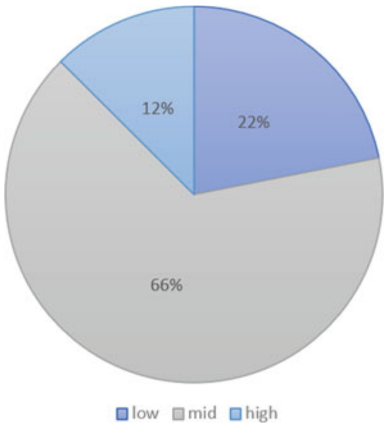


Fig. 8 Digital transformation dimensions—Latin American universities

Fig. 9 Digital transformation classification—Colombian public universities



technological, or organizational. Finally, 12% of public universities in Colombia have carried out internal digital transformation processes from all three perspectives.

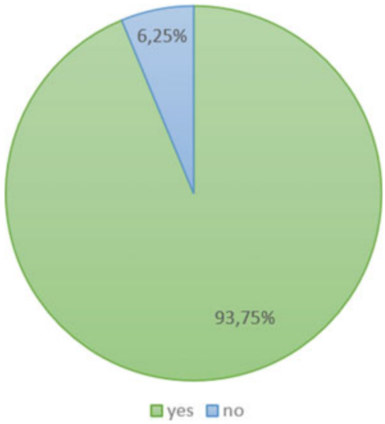


Fig. 10 Social perspective of digital transformation—Colombian public universities

In Fig. 10, it can be observed that 93.75% of the public universities in Colombia (30 universities) have executed digital transformation processes from the social perspective, while 6.25% (2 universities) do not evidence any digital transformation from this perspective.

Figure 11 shows that 88% of the public universities in Colombia (28 universities) have not executed digital transformation processes from the organizational perspective, while 12% (four universities) evidence digital transformation from this perspective.

Figure 12 illustrates that 81% of the public universities in Colombia (26 universities) have executed digital transformation processes from the technological perspective, while 19% (six universities) do not evidence any digital transformation from this perspective.

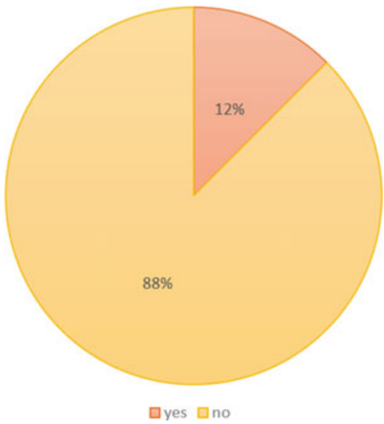


Fig. 11 Organizational perspective of digital transformation—Colombian public universities

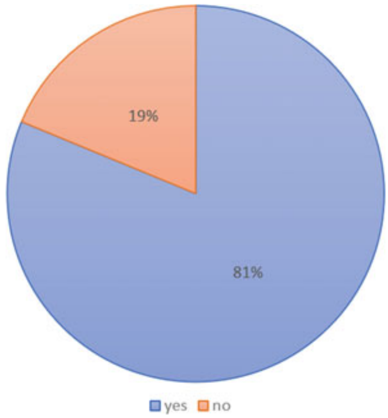


Fig. 12 Technological perspective of digital transformation—Colombian public universities

Taking into account the dimensions considered by Benavides et al. (2020) and contrasting them with the data collected, Fig. 13 shows the digital transformation dimensions radar applied to the Colombian public universities.

Figure 13 indicates that universities have prioritized the dimensions of teaching (24 universities) and human resources (22 universities), followed by infrastructure

Fig. 13 Digital transformation dimensions—Colombian public universities

(16 universities). Next, four universities have considered the dimensions of governance, information, business processes, and administration of DT. After that, three universities have considered the curriculum dimension, one university has considered the extension and research dimensions, and none have considered marketing.

3.3 Digital Transformation Dimensions Carried Out by Latin American Universities

Taking into account the main dimensions involved in the digital transformation of higher education institutions, defined in literature as human resources, research, teaching, curricula, business process transformation, infrastructure, governance of DT, administration, marketing, information, and university extension or outreach (Benavides et al., 2020), universities have addressed the following:

3.3.1 From the Social Perspective

Figure 14 illustrates the dimensions that have been considered from the social perspective.

Human resources dimension: Under the influence of the digital environment, the classical approaches to labor resources, jobs, and labor relations are being transformed, and the needs and demands for employees' competencies are changing. New rules of business and organization work are being formed in almost all spheres of people's activity, including training, management, and determination of the content of the work itself (Panichkina et al., 2019). In that sense, strategic actions have been focused on developing different strategies, such as training teachers in virtual learning environments, virtual learning objects, and implementing new ICTs to support the training process and reflect pedagogical innovation and institutional mission. Secondly, digital transformation requires changing management and the development of capacities as entrepreneurs and soft skills in students and graduates;

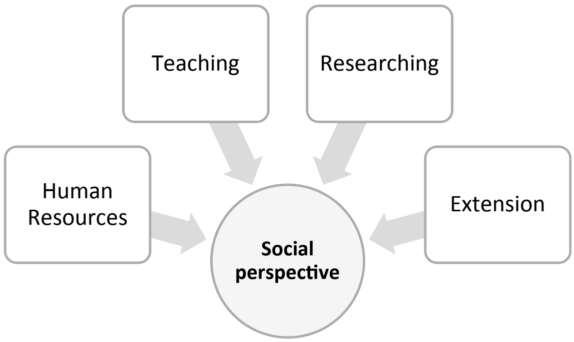


Fig. 14 Social perspective at universities

the promotion of the use of digital technologies and Industry 4.0 in the missionary processes of teaching, research, and extension, as well as the promotion and adoption of a digital culture through training, awareness-raising, and reorientation of some processes, additionally offering courses, seminars, and specializations in digital transformation to society. Universities have made progress in the promotion and adoption of a digital culture through training, awareness-raising, and reorientation of some processes, as well as integrating innovative computer technologies for directing and supporting their academic and administrative processes.

Teaching dimension (Bagdasarian et al., 2020): Based on the mission of the university and considering the digital transformation as changes made by the external environment in the context of global developments, we believe that the conditions created here and now for the formation of human capital that can increase labor productivity in the digital economy are indisputable. We understand the need to form the internal ecosystem of the university, focusing on digital changes that will lead to updating the competence model that graduates must meet in order to enter the labor market of the digital economy. This is also indicated by public and professional discussions regarding the need to develop and implement programs for advanced training and professional retraining in the required competencies of the digital economy.

With progressive technological advancements in computer software, Web applications, and data network bandwidth, e-learning systems have changed the educational ecosphere of schools, universities, and corporate training systems. This phenomenon has drastically changed how teaching and learning are conventionally administered and managed (Tay & Low, 2017). In that sense, universities have oriented their strategies to improve internal talent, goods, materials, and financial resources for the planning and promotion of the development of different face-to-face, remote, and virtual modalities, which allows them to be positioned at a local, regional, national, and international level. Also, they have implemented a virtual search library that allows students to carry out pertinent research to develop their academic and research activities. Finally, they have established important alliances among online courses enterprises.

Research dimension: This dimension has also been influenced by DT. Research is forced to align with the digital transformation to fulfil the requirement and expectations of actors involved in the research processes (Rodrigues, 2017). Universities are considering the promotion of the use of digital technologies and Industry 4.0 in the missionary research process.

Extension dimension: This dimension considers the establishment of integration links between universities, specialized secondary schools, major enterprises, and regional public administration. It also considers the opportunity to improve the mechanisms of adaptation of graduates to the labor market, where the qualification of workers is enhanced in terms of turning them into "appendages to digits," reducing the proportion of mid-skill workers, who are easier to replace with digital technologies (Benavides et al., 2020). Additionally, it is necessary to consolidate processes of internationalization of higher education while maintaining the appreciation of the culture itself and territorial development, which implies encouraging and innovating teaching and learning approaches, virtual and open education, multilingualism, participation in knowledge networks of a different nature, and the visibility of the institutional work beyond the national environment.

3.3.2 Organizational Perspective

Figure 15 shows the dimensions that have been considered by universities in Latin America from the organizational perspective.

Business process transformation dimension: In the business process context, digital transformation forces companies to develop, change, and adapt to the different stages of digital evolution. In other words, digital transformation, being an organizational transformation, enables the university to create, improve, re-invent operational processes, and replace traditional services with digital ones to simplify the processes involved in educational service delivery and operational complexity (Benavides et al., 2020). The changes, which are largely in the business process, induce changes in other processes, strategies, and the firm as a whole (Krell & Gale, 2005). In this situation, in HEIs, the implementation of management by macroprocesses requires a digital transformation that involves cultural change in organizational matters. This strategy involves a deep review of organizational models, processes, people, culture, and infrastructure, with a focus on the user, operational improvement, accuracy, and data quality. Also considered was the creation of a Faculty of Distance and Virtual Modality as a special unit of an academic and administrative nature with autonomy and organic structure.

Administration dimension: Benavides et al. (2020) identified four aspects to consider in this dimension: improving existing work and operations, financial and technological aspects, reorganizing administrative units, and making informed decisions. From the analysis carried out, it was found that this dimension has been approached from improving existing work and operations; creating a new scheme to solve problems in less time, more efficiently; and not only in terms of administrative management but also for students. For instance, some strategies were implemented for online governance and access to information for internal and external

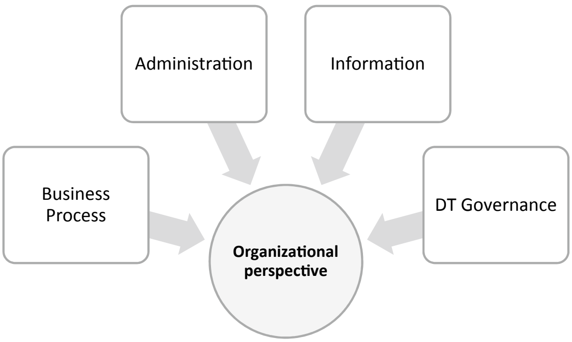


Fig. 15 Organizational perspective

audiences; electronic invoicing and modernization of IS are also required. Additionally, authors recognize the importance of financial and technological aspects, realizing that the digital transformation requires large investments, and goals aimed at efficiently managing resources. In the financial aspect, many challenges in digital transformation in HEIs are related to their constraints due to the large investments required to implement a digital transformation project where it is needed to get rid of the past and adopt new and advanced technologies considering the capabilities of each organization (Benavides et al., 2020). This is the reason universities must commit to managing their resources for the modernization of the physical and technological infrastructure.

Information dimension: Meijer and Bekkers (2015), expresses that the introduction of ICT entails an immanent change in the way organizations process information that enhances the organization's reflexivity, emphasizing informational capabilities rather than automating ICT capabilities. This dimension in the digital transformation is a very valuable asset; therefore, it must be aligned and consistent with the business architecture of the HEI (Benavides et al., 2020). Universities considered that this component has consisted of strengthening the technological infrastructure to provide adequate institutional responses to the needs of access to information and knowledge management, connectivity and collaborative work with academic peers, research networks, and national and international institutions.

Digital transformation governance dimension: A major challenge faced by organizations today is how to adopt and leverage new digital technologies, as the ability to promote digital transformation is in large part determined by a clear digital strategy, enabled by a culture of change, risk-taking, and innovation, supported by its leaders (Stolze et al., 2018). As a consequence, the digital transformation governance dimension exists in HEIs because, for highly digitized organizations, it is crucial to understand and manage digital innovations (Bresinsky & Von Reusner, 2018; Sullivan & Staib, 2018). Consequently, Meijer and Bekkers (2015) implied that present e-government initiatives follow an already existing trail: they have built upon grown practices and established interests that can only be understood when taking into account the history, the power relations, and the dominant culture (like beliefs and even ideology) of the involved organizations or policy sector.

One of the main tools that make this challenge possible is the enterprise architecture, which is a solution that enables the enterprise architects and business partners to have a digital representation of business strategy, business processes, and resources. Consequently, such representation allows digital transformation leaders in charge of digital transformation to have a better understanding of the internal relationships throughout the company, integrate software, and resources with the business, foresee the influence of their decisions, and plan according to the findings. One proposal is the creation of a technological observatory and application of business architecture inside the university.

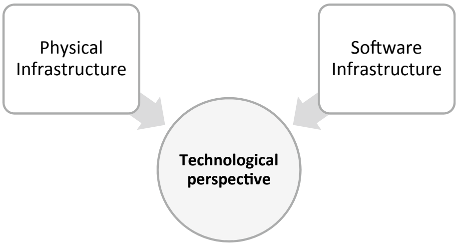


Fig. 16 Technological perspective

3.3.3 Technological Perspective

Figure 16 shows the dimensions that have been considered by universities in Latin America from the technological perspective.

Although the digital transformation in HEIs does not focus purely on technological infrastructure, it does become a vital support for its achievement. The digital transformation in HEIs is supported by an appropriate IT infrastructure to meet the organization's requirements and infrastructure that may help adopt effective policies and practices that support teaching, learning, and administrative processes arising in the digital age (Benavides et al., 2020). A narrow focus just on infrastructure negatively impacts the implementation of DT, which deals with infrastructure and workplace IT and focuses on a common group infrastructure and common tools for communicating and cooperating more efficiently (Singh & Hess, 2017).

Infrastructure dimension: As expressed by Benavides et al. (2020), digital transformation seen from the infrastructure dimension has diverse aspects, such as digital and physical infrastructure for teaching, data and security infrastructure, and software infrastructure for HEIs. In this specific analysis, universities have considered the digital and physical infrastructure for teaching using platforms, implementing laboratory simulators as virtual training tools that complement the laboratory practices online and in person, and creating a smart campus as part of the DT. Also, centers for information and communication technologies have been created as an institutional strategy for the consolidation of the project aims to promote and strengthen the use of ICTs. In terms of data and security infrastructure, universities propose to modernize their security platform. As well, for software infrastructure, universities propose integrating the information systems that correspond to the nature, size, and complexity of the university and establishing a virtual platform that serves all internal and external university instances, e.g., the integration of the academic-administrative technological platform to track and support the academic and administrative processes of the institution. Additionally, a change in the structure and functions of information and communication technologies is proposed to implement the IT governance with standards of institutional scope. This new purpose implies the roles of counsellor, director, and supervisor, who will define goals and issue guidelines and policies on IT matters to offer services and solutions, all in accordance with the institutional needs and the guidelines of the digital governance policies.

4 Conclusions

Universities have initially focused their efforts on digital transformation from a social perspective, given in the dimensions of education and human resources. This situation is evidenced by the need to understand and disseminate what digital transformation is, its importance, and how to approach this new challenge.

It stands out from the study that universities that have advanced in digital transformation processes from the organizational perspective have also done so from the social and technological perspectives; for this reason, they have been classified in the high category of digital transformation. Likewise, it can be concluded that universities that have not made progress in digital transformation from a technological perspective have not done so from other perspectives (social or organizational) either.

The most important digital transformation efforts at Latin American universities have been gestated and driven not internally but by external factors (as an urgent response to the new scenario framed by the Covid-19 pandemic, or government policies in the case of Colombia), which have forced them to respond to and meet the pressing needs of the academic community and society.

Acknowledgements Thanks to Daniel Gonzalez Núñez, an industrial engineering student (Universidad Nacional de Colombia) who very kindly programmed the MCA algorithm in Python.

Appendix: Databases

Colombian public universities	HML DT	Social DT	Organizational DT	Tech DT
University 1	High	Yes	Yes	Yes
University 2	High	Yes	Yes	Yes
University 3	High	Yes	Yes	Yes
University 4	High	Yes	Yes	Yes
University 5	Low	Yes	No	No
University 6	Low	Yes	No	No
University 7	Low	Yes	No	No
University 8	Low	Yes	No	No
University 9	Low	Yes	No	No
University 10	Low	No	No	Yes
University 11	Low	No	No	No
University 12	Mid	Yes	No	Yes
University 13	Mid	Yes	No	Yes

(continued)

(continued)

Colombian public universities	HML DT	Social DT	Organizational DT	Tech DT
University 14	Mid	Yes	No	Yes
University 15	Mid	Yes	No	Yes
University 16	Mid	Yes	No	Yes
University 17	Mid	Yes	No	Yes
University 18	Mid	Yes	No	Yes
University 19	Mid	Yes	No	Yes
University 20	Mid	Yes	No	Yes
University 21	Mid	Yes	No	Yes
University 22	Mid	Yes	No	Yes
University 23	Mid	Yes	No	Yes
University 24	Mid	Yes	No	Yes
University 25	Mid	Yes	No	Yes
University 26	Mid	Yes	No	Yes
University 27	Mid	Yes	No	Yes
University 28	Mid	Yes	No	Yes
University 29	Mid	Yes	No	Yes
University 30	Mid	Yes	No	Yes
University 31	Mid	Yes	No	Yes
University 32	Mid	Yes	No	Yes

Latin American universities	HML DT	Social DT	Organizational DT	Tech DT
Country 1	Mid	Yes	Yes	Yes
Country 2	Mid	Yes	Yes	Yes
Country 3	Mid	Yes	Yes	Yes
Country 4	High	Yes	Yes	Yes
Country 5	Mid	Yes	No	No
Country 6	Mid	Yes	No	No
Country 7	Mid	Yes	No	No
Country 8	Mid	Yes	No	No
Country 9	Mid	Yes	No	No
Country 10	Mid	No	No	Yes

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Artificial Intelligence and Industry 4.0 Across the Continent: How AI and 4.0 are Addressed by Region

Nilda Yangüez Cervantes and Carlos Mario Zapata-Jaramillo

Abstract Artificial intelligence is nowadays a well-known technology in Latin America, while Industry 4.0 is a hot trend with different approaches in our region. We recognize Industry 4.0 is supported in some aspects by artificial intelligence. This fact is validated by the work of some researchers in our region. The mature work in some artificial intelligence techniques such as natural language processing, digital image processing, neural networks, and fuzzy and intelligent systems is complemented by the emerging work on Industry 4.0. Consequently, in this chapter, we summarize the trends related to artificial intelligence and Industry 4.0 in Latin America by using domain models, a previous form of class diagrams. We perform a systematic literature review to this aim for identifying the main elements of the domain model. Different terms are unified as a way to compare the work performed in the Latin America region related to such technologies. Our graphical summary can be used throughout this book for understanding the close relationship artificial intelligence and Industry 4.0 exhibits in our region and analyzing the contents of the different chapters.

Keywords Artificial intelligence · Industry 4.0 · Graphical summary · Domain models · Trends · Relationships

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1 Introduction

Latin American researchers have been active for publishing topics related to artificial intelligence (AI), which is a term coined in the 1950s. In fact, the Inter-American Development Bank has a study with the current status related to AI in twelve Latin American countries (Gómez Mont et al., 2020), highlighting some work in Uruguay, Colombia, Argentina, Chile, and Mexico for developing AI-based systems. According to Baygin et al. (2016), Industry 4.0 is a term coined in 2011, so we expect more development in the future of the Latin American countries, even though some publications are starting to emerge related to this topic.

Latin American researchers are starting to bridge links between AI techniques and Industry 4.0 thematic areas since both areas come from the same basis. For example, natural language processing—a classical AI technique—can be used in big data and analytics, two of the new thematic areas of Industry 4.0. Similarly, digital image processing can be used in autonomous robots and augmented reality. Since we have multiple examples about such relationship, we need a way to explore such trends and recognize how AI and Industry 4.0 have been addressed in Latin America.

Regarding this need, in this chapter, we propose a model for summarizing the recent work related to artificial intelligence and Industry 4.0 in Latin America. Such a model is based on knowledge representation by using domain models (Larman, 2005), a previous version of the class diagram. The process for developing the domain models includes a collection of published documents about AI (Acosta, 2018; Almonacid et al., 2018; Alvarez-Jimenez et al., 2019; Arista et al., 2021; Arroyo-Fernández et al., 2019; Barriga & Besoain, 2020; Bravo et al., 2011; Bugnon et al., 2020; Calderon-Vilca et al., 2019; Cardona et al., 2019; Castañeda-Miranda & Castaño-Meneses, 2020; Castro-Gutierrez et al., 2019; Chavez-Badiola et al., 2020; Cornejo et al., 2020; Cruz & Vera, 2020; Delgado et al., 2018; Escandón, 2018; Esteva et al., 2007; Fernandez-Cortez et al., 2020; Flores-Leonar et al., 2020; Fornaciari et al., 2020; Gallo et al., 2020; Garcés et al., 2017; Gómez-Peralta & Bokhimi, 2020; Hernandez-Garcia et al., 2018; Hurtado & Bathe, 2003; Jácome et al., 2018; Janssen et al., 2020; Jimenez et al., 2020; Kruk et al., 2020; Lopez-Rincon & Starostenko, 2018; Montiel-González et al., 2021; Nieto-Chaupis, 2018a, 2018b; Nuñez-Fernández, 2019; Picos-Benítez et al., 2020; Pino et al., 2018; Proaño et al., 2019; Rodriguez et al., 2019b; Rodríguez et al., 2018c; Saenz et al., 2021; Salazar-Ruiz et al., 2008; Tello-Morales et al., 2018; Toscano et al., 2019; Villegas-Ch et al., 2019; Viloria et al., 2020; Xu et al., 2018) and Industry 4.0 (Arbulu et al., 2018; Ardila et al., 2020; Ariza et al., 2021; Bula et al., 2019; Caiza et al., 2019; Calvo et al., 2020; Ccalli, 2020; Cruz et al., 2018; Estrin et al., 2020; Fernández et al., 2020; Fuente-Mella et al., 2020; Garcia et al., 2018a, 2018b; Gil & Zapata-Madrigal, 2019; Giorgio & Mon, 2019; Henao-Hernández et al., 2019; Hinojosa-Palafox et al., 2019; Jácome & Jácome, 2019; Luna et al., 2018; Miranda et al., 2017; Mon et al., 2018; Naranjo et al., 2018; Neira et al., 2020; Ponce et al., 2019; Ramos et al., 2020; Ravina-Ripoll et al., 2019, 2020; Rodriguez et al., 2018a; Rodríguez et al., 2018b, 2019a; Rossit & Tohmé, 2018; Rossit et al., 2019, 2020; Salazar et al., 2018;

Sánchez et al., 2018; Tang et al., 2016; Velásquez et al., 2019; Vo et al., 2020; Yamao & Lescano, 2020; Zamora et al., 2017) in Latin America based on a systematic literature review and an extraction of the terms related to the topics. Our domain models resemble the way AI and Industry 4.0 are used in Latin America, so they can also be consulted by the readers of this book in order to compare the proposed solutions with those resulting from our review and synthesis.

The main structure of this chapter is the following: In Sect. 2, we provide some definitions; in Sect. 3, we perform the review and we develop the domain models; in Sect. 4, we analyze the results. Section 5 is devoted to conclusions and some future work.

2 Definitions

2.1 Artificial Intelligence

Gómez Mont et al. (2020) discussed some of the main elements of a computational system to be considered AI-based:

- **Environment**: It is real or virtual object to be perceived by the system
- **Perceptrons**: They are sensors for capturing raw data from the environment
- **Actuators**: They are physical/informational devices for generating actions in the environment
- **AI system**: It is a computational system with algorithms for constructing models with the aim of predicting, classifying, and delivering actions to be performed by the actuators; the algorithms comprise the operational logic of the computational system, and they can be materialized by using different techniques, like neural networks, fuzzy logic, machine learning, etc.

2.2 Industry 4.0

Baygin et al. (2016, p. 1) defined industrial revolutions as "cases that shed light on our daily life and these revolutions have led to significant improvements." They recall Industry 4.0 was coined in 2011 by the German government for resembling computerized manufacturing and intelligent production. Nine technological fields are associated with Industry 4.0 (Baygin et al., 2016): (i) big data and analytics; (ii) additive manufacturing; (iii) augmented reality; (iv) cloud computing; (v) cybersecurity; (vi) Internet of Things; (vii) horizontal and vertical system integration; (viii) simulation, and (ix) autonomous robots.

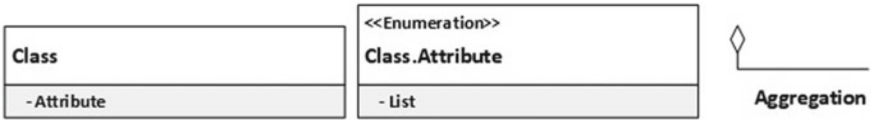

Fig. 1 Symbols of the domain models. Larman (2005) *Source* adapted from

2.3 Domain Models

According to Larman (2005), a domain (conceptual) model is a visual representation of the key concepts belonging to a domain. This kind of models is useful for specifying software systems in order to define their main requirements. However, we are more interested in this chapter about the appearance of the domain models as graphical summaries of the information related to a certain domain. We use some symbols of the class diagram for developing such summaries (Fig. 1) with the following descriptions:

- **Classes**: They are groups, sets, or kinds sharing the same attributes and the attributes. They can be expressed in nouns and noun phrases in two-box rectangles, one for the name of the class and other for the attributes.
- **Enumerations**: They are a special kind of class with the stereotype "enumeration" in which the first box is related to the attribute and the class and the second one is related to the list of values the attribute can take.
- **Aggregation:** It is the relationship between two classes for expressing parts and wholes.

3 Knowledge Representation About Trends of AI and Industry 4.0 in Latin America

Latin American researchers have been working on AI some years ago, but Industry 4.0 is relatively new. Since both trends are intertwined, we need a mechanism for representing knowledge about such trends in Latin America in order to analyze the results. This knowledge representation is proposed in this section.

The first step is the realization of a systematic literature review with some conditions: (i) We select papers/chapters from three databases (ScienceDirect, Springer, and IEEE Xplore) since they cover our needs in terms of documents; (ii) at least one author should belong to a Latin American university; and (iii) each document should explicitly mention either AI or Industry 4.0 in their contents. We select 47 chapters/papers belonging to AI (Acosta, 2018; Almonacid et al., 2018; Alvarez-Jimenez et al., 2019; Arista et al., 2021; Arroyo-Fernández et al., 2019; Barriga & Besoain, 2020; Bravo et al., 2011; Bugnon et al., 2020; Calderon-Vilca et al., 2019; Cardona et al., 2019; Castañeda-Miranda & Castaño-Meneses, 2020; Castro-Gutierrez et al., 2019; Chavez-Badiola et al., 2020; Cornejo et al., 2020; Cruz &

Vera, 2020; Delgado et al., 2018; Escandón, 2018; Esteva et al., 2007; Fernandez-Cortez et al., 2020; Flores-Leonar et al., 2020; Fornaciari et al., 2020; Gallo et al., 2020; Garcés et al., 2017; Gómez-Peralta & Bokhimi, 2020; Hernandez-Garcia et al., 2018; Hurtado & Bathe, 2003; Jácome et al., 2018; Janssen et al., 2020; Jimenez et al., 2020; Kruk et al., 2020; Lopez-Rincon & Starostenko, 2018; Montiel-González et al., 2021; Nieto-Chaupis, 2018a, 2018b; Nuñez-Fernández, 2019; Picos-Benítez et al., 2020; Pino et al., 2018; Proaño et al., 2019; Rodriguez et al., 2019b; Rodríguez et al., 2018c; Saenz et al., 2021; Salazar-Ruiz et al., 2008; Tello-Morales et al., 2018; Toscano et al., 2019; Villegas-Ch et al., 2019; Viloria et al., 2020; Xu et al., 2018) and 40 belonging to Industry 4.0 (Arbulu et al., 2018; Ardila et al., 2020; Ariza et al., 2021; Bula et al., 2019; Caiza et al., 2019; Calvo et al., 2020; Ccalli, 2020; Cruz et al., 2018; Estrin et al., 2020; Fernández et al., 2020; Fuente-Mella et al., 2020; Garcia et al., 2018a, 2018b; Gil & Zapata-Madrigal, 2019; Giorgio & Mon, 2019; Henao-Hernández et al., 2019; Hinojosa-Palafox et al., 2019; Jácome & Jácome, 2019; Luna et al., 2018; Miranda et al., 2017; Mon et al., 2018; Naranjo et al., 2018; Neira et al., 2020; Ponce et al., 2019; Ramos et al., 2020; Ravina-Ripoll et al., 2019, 2020; Rodriguez et al., 2018a, 2018b, 2019a; Rossit & Tohmé, 2018; Rossit et al., 2019, 2020; Salazar et al., 2018; Sánchez et al., 2018; Tang et al., 2016; Velásquez et al., 2019; Vo et al., 2020; Yamao & Lescano, 2020; Zamora et al., 2017).

The second step is the collection of two corpora (one for AI and one for Industry 4.0) with the included documents for performing a terminological analysis about a list of terms with frequencies in the document. We exclude the common stop-words, like articles, prepositions, and adverbs. We omit information related to: (i) the authors and affiliations; (ii) headers and footers of the published papers/chapters; (iii) keywords, since some of the documents lack this information; (iv) acknowledgments and other additional sections; and (v) references. We omit such information because we are interested in the contents of the documents and we try to avoid bias by repetition of some information. The resulting terms from each corpus with the associated frequency are included in Tables 1 and 2. We also delete some words related to the usual structure of a paper, like abstract, introduction, conclusions, and future work; terms like paper and chapter are also deleted from the list. Finally, we group some similar terms (e.g., the same word in singular and plural, some derivations of the same term in noun and adjective, and some acronyms with their components). We also consider common combinations of two and three words in the text with their frequency. Hence, we select the following combinations with their frequency from the AI corpus like neural networks (169), artificial intelligence (149), time series (87), machine learning (82), gold standard (81), neural network (79), data governance (69), fake reviews (61), climatic hazard (50), traffic light (41), multi-agent (36), recommender systems (34), fuzzy logic (33), artificial neural (28), energy efficiency (28), video game (25), music composition (23), production management (18), artificial neural networks (29), multi-agent systems (26), time series forecasting (10), machine learning algorithms (9), ecological anti-disaster (7), video game development (7), artificial intelligence techniques (6), and traffic light phases (6).

Also, we select the following combinations with their frequency from the Industry 4.0 corpus like real time (139), iot devices (76), cyber-physical (70), internet things

Table 1 Terms and frequency from the AI corpus

Term	Fr	Term	Fr	Term	Fr
Data	1234	Analysis	237	Error	147
Model(s)	1093	Development	222	Evaluation	143
System(s)	760	Similarity	210	Crop	143
Based	727	Layer	208	Average	142
Method(s)	564	Ann	415	Structure	139
Value(s)	540	Test	197	Described	137
Algorithm(s)	504	Social	191	Behavior	137
Time	492	Traffic	191	Presented	137
Information	482	User	188	Techniques	135
Feature(s)	434	Machine	187	Important	134
Network(s)	421	Variables	185	Vector	133
Ai	403	Point	184	Robot	132
Number	392	Prediction	180	Output	131
Agent(s)	384	State	170	Energy	129
Learning	381	Parameters	169	Management	128
Image(s)	376	Standard	166	Present	127
Concept(s)	349	Real	165	Dataset	126
Classification	336	Soil	165	Selected	126
Tag(s)	314	Human	165	Quality	125
Training	301	Series	162	Research	124
Performance	294	Function	161	Flame	124
Irrigation	294	Condition	161	Level	123
Process	290	Accuracy	160	Section	123
Water	284	Content	157	Sensors	123
Control	268	Knowledge	154	Environment	120
Order	252	Temperature	150	Simulation	120
Group(s)	252	Summaries	149	Game	120
Production	251	Application	147	Climatic	119

Source The Authors

(64), big data (62), machine learning (45), product design (44), smart cities (43), virtual reality (38), cloud computing (37), data management (33), physical systems (32), things iot (27), data analytics (24), manufacturing systems (24), industrial revolution (21), iot device (19), iot systems (18), fourth industrial (16), computer vision (15), cyber-physical systems (30), internet things iot (23), fourth industrial revolution (12), big data analytics (11), real-time processing (9), chemical product design (8), human–robot interaction (8), human–machine interaction (6), and machine learning algorithms (5).

Table 2 Terms and frequency from the Industry 4.0 corpus

Term	Fr	Term	Fr	Term	Fr
System(s)	977	Properties	201	Decision	116
Product(s)	835	Real	198	Cosmetic	112
Data	832	Order	187	Agents	112
Industry(ial)	676	Case	181	Research	111
Process(es)	670	Performance	180	Emulsion	110
Time	481	Emulsified	169	Set	109
Model(s)	447	Analysis	165	Functional	109
Services	446	Variables	164	Maintenance	107
Device(s)	435	Scheduling	159	Temperature	103
Manufacture(ing)	434	Environment	154	Size	101
Iot	413	Integration	152	Knowledge	101
Production	384	Software	150	Quality	100
Information	366	Cloud	149	Method	99
Machine(s)	349	Number	144	Average	99
Design	333	Web	140	Elements	98
Components	308	Learning	139	Automation	98
Physical	307	Virtual	139	Interaction	97
Sensor(s)	283	Problem	137	Needs	97
Network(s)	263	Ontology	136	Efficiency	97
Application	254	Computing	133	Monitoring	97
Control	253	Value	127	Protocol	95
Technology(ies)	251	Matching	127	Message	95
Smart	248	Human	126	Integrated	92
Communication	226	Management	125	Presented	92
Layer	217	Processing	123	Platform	91
Architecture	215	User	122	Response	90
Development	211	Implementation	121	Semantic	90
Level	205	Tools	119	Implemented	89

Source The Authors

The third step is the development of the domain models. We use individual terms, but we also consider common combinations of words for including the vast generality of topics included in the papers/chapters selected. Some words like domain, technological field, and name are added for giving clarity to the representations. Some combinations are modified for adapting to the standard terms used in the literature; e.g., "virtual reality" is changed by "augmented reality" for resembling the technological field defined by Baygin et al. (2016). Be advised that the common

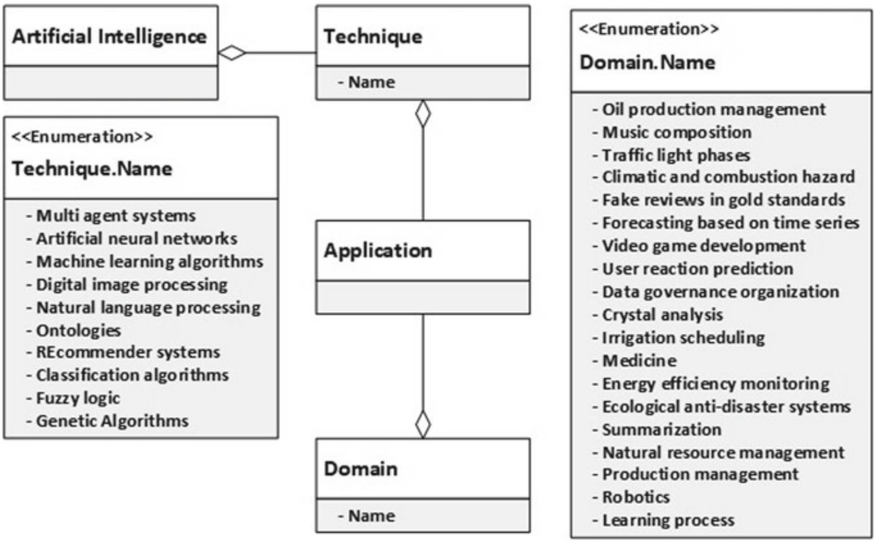

Fig. 2 Resulting domain model about AI. *Source* The Authors

combinations are used as names of tools, technological fields, domains, and techniques since the applications are combinations of the techniques and domains—in the case of AI—or technological fields and tools—in the case of Industry 4.0.

The resulting domain models are depicted in Figs. 2 and 3. Such models are used for analyzing the results in the next section. Even though the word *name* is not listed as one of the more frequent words in Tables 1 and 2, we need it for relating the names of the tools we find in the literature. Similarly, we use the words *technological field* and *domain,* since they both reflect the usual names of such concepts in the specialized literature. Application is an intermediate class in both models.

4 Results and discussion

The domain models we developed in the previous section can be used for analyzing the trends related to AI and Industry 4.0 in Latin America. The documents we select are summarized in Tables 3 and 4 according to the fields we have in the domain models. We also add the country of the researcher belonging to Latin America. Similarly, the readers of this book can analyze the chapters of the book regarding the trends about AI and Industry 4.0 for understanding digital transformation in Latin America.

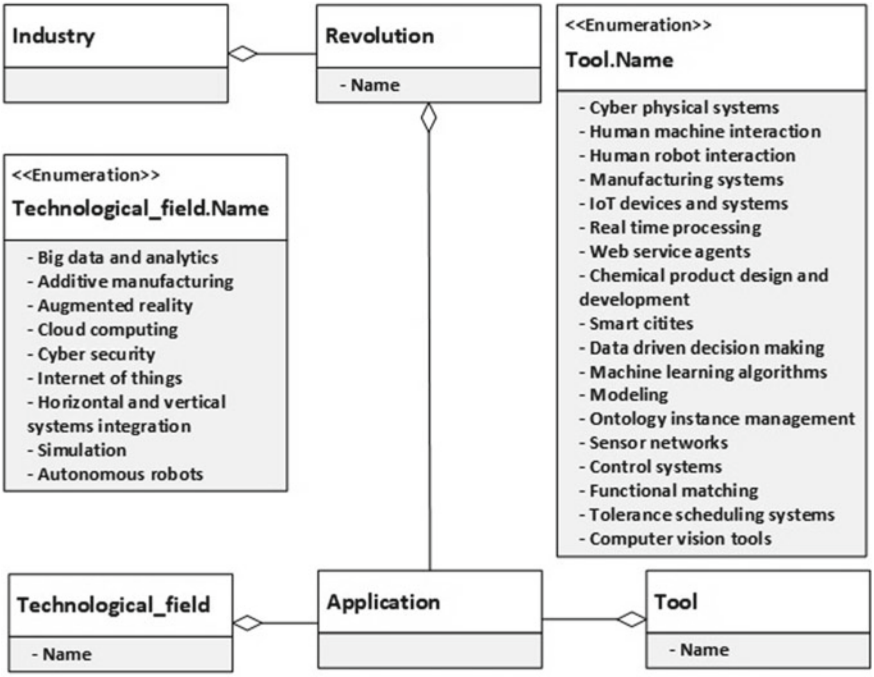

Fig. 3 Resulting domain model about Industry 4.0. *Source* The Authors

5 Conclusions and Future Work

In this chapter, we developed two domain models related to AI and Industry 4.0 in Latin America in order to analyze the trends about such topics. We followed a process including a systematic literature review, a terminological unification, and the development of the domain models. Also, we used the developed models for summarizing the contents of the papers/chapters selected in terms of the fields identified in the domain models. This kind of analysis can be extended by the readers of this book for the rest of the chapters we include in the book.

Future work should be devoted to some lines:

- Including more documents for improving the accuracy of the results
- Including more elements of the documents to be analyzed: verbs, adjectives, and adverbs
- Developing a statistical analysis about the trends

Table 3 Analysis of the documents related to AI

References	Country	Name of the domain	Name of the technique
Gallo et al. (2020)	Argentina	User reaction prediction	Machine learning algorithms
Janssen et al. (2020)	Argentina	Data governance organization	Machine learning algorithms
Montiel-González et al. (2021)	Mexico	Climatic and combustion hazard	Artificial neural networks
Pino et al. (2018)	Chile	Climatic and combustion hazard	Classification algorithms and digital image processing
Gómez-Peralta and Bokhimi (2020)	Mexico	Crystal analysis	Artificial neural networks
Jimenez et al. (2020)	Colombia	Irrigation scheduling	Multi-agent systems
Arista et al. (2021)	Mexico	Medicine	Machine learning algorithms and classification algorithms
Garcés et al. (2017)	Chile	Energy efficiency monitoring	Machine learning algorithms
Castañeda-Miranda and Castaño-Meneses (2020)	Mexico	Ecological anti-disaster systems	Artificial neural networks and fuzzy logic
Arroyo-Fernández et al. (2019)	Mexico	Summarization	Machine learning algorithms and natural language processing
Picos-Benítez et al. (2020)	Mexico	Ecological anti-disaster systems	Artificial neural networks and genetic algorithms
Salazar-Ruiz et al. (2008)	Mexico	Ecological anti-disaster systems	Artificial neural networks and machine learning algorithms
Chavez-Badiola et al. (2020)	Mexico	Medicine	Machine learning algorithms
Esteva et al. (2007)	Argentina	Medicine	Artificial neural networks
Bravo et al. 2011)	Venezuela	Oil production management	Multi-agent systems
Viloria et al. (2020)	Colombia, Honduras	User reaction prediction	Multi-agent systems

(continued)

Table 3 (continued)

References	Country	Name of the domain	Name of the technique
Flores-Leonar et al. (2020)	Mexico	Ecological anti-disaster systems	Machine learning algorithms
Hurtado and Bathe (2003)	Colombia	Forecasting based on time series	Machine learning algorithms
Delgado et al. (2018)	Peru	Natural resource management	Recommender systems
Lopez-Rincon and Starostenko (2018)	Mexico	Music composition	Artificial neural networks, genetic algorithms, multi-agent systems
Xu et al. (2018)	Argentina	User reaction prediction	Ontologies and recommender systems
Escandón (2018)	Peru	Video game development	Genetic algorithms
Tello-Morales et al. (2018)	Ecuador	Medicine	Digital image processing
Almonacid et al. (2018)	Argentina	Natural resource management	Artificial neural networks
Hernandez-Garcia et al. (2018)	Mexico	Crystal analysis	Natural language processing
Jácome et al. (2018)	Ecuador	Traffic light phases	Fuzzy logic, multi-agent systems, digital image processing
Rodríguez et al. (2018a)	Argentina	Forecasting based on time series	Artificial neural networks
Nieto-Chaupis (2018a)	Peru	User reaction prediction	Genetic algorithms
Acosta (2018)	Colombia	User reaction prediction	Digital image processing
Castro-Gutierrez et al. (2019)	Peru and Chile	Medicine	Digital image processing
Nieto-Chaupis (2018b)	Peru	User reaction prediction	Genetic algorithms
Bugnon et al., 2020)	Argentina	Medicine	Artificial neural networks
Rodriguez et al. (2019b)	Argentina, Colombia, Mexico	Forecasting based on time series	Artificial neural networks
Toscano et al. (2019)	Uruguay	Forecasting based on time series	Machine learning algorithms
Nuñez-Fernández (2019)	Peru	User reaction prediction	Digital image processing and artificial neural networks

(continued)

Table 3 (continued)

References	Country	Name of the domain	Name of the technique
Alvarez-Jimenez et al. (2019)	Colombia	Medicine	Artificial neural networks
Villegas-Ch et al. (2019)	Ecuador	Learning process	Recommender systems
Calderon-Vilca et al. (2019)	Peru	Medicine	Artificial neural networks
Proaño et al. (2019)	Ecuador	Video game development, traffic light phases	Multi-agent systems
Cardona et al. (2019)	Colombia	Robotics	Machine learning algorithms
Barriga and Besoain (2020)	Chile	Video game development and learning process	Machine learning algorithms and genetic algorithms
Cornejo et al. (2020)	Mexico	Climatic and combustion hazard	Machine learning algorithms
Fernandez-Cortez et al. (2020)	Mexico	Data governance organization	Genetic algorithms
Cruz and Vera (2020)	Peru	Production management	Artificial neural networks
Fornaciari et al. (2020)	Argentina	Fake reviews in gold standards	Natural language processing
Kruk et al. (2020)	Argentina and Uruguay	Ecological anti-disaster systems	Classification algorithms
Saenz et al. (2021)	Mexico	Robotics	Classification algorithms

Source The Authors

Table 4 Analysis of the documents related to Industry 4.0

References	Country	Name of the tool	Name of the technological field
Ramos et al. (2020)	Mexico	Smart cities	Internet of Things
Calvo et al. (2020)	Colombia	Chemical product design and development	Integration
Fuente-Mella et al. (2020)	Chile	Manufacturing systems	Integration
Fernández et al. (2020)	Argentina	Computer vision tools and machine learning algorithms	Autonomous robots
Ariza et al. (2021)	Colombia	Iot devices and systems	Internet of Things
Tang et al. (2016)	Mexico	Cyber-physical systems and iot devices and systems	Internet of Things
Rossit and Tohmé (2018)	Argentina	Cyber-physical systems and manufacturing systems	Additive manufacturing
Ccalli (2020)	Peru	Modeling	Simulation
Ardila et al. (2020)	Colombia	Data-driven decision making and manufacturing systems	Additive manufacturing
Miranda et al., 2017)	Mexico and Cuba	Cyber-physical systems	Internet of Things
Naranjo et al. (2018)	Ecuador	Iot devices and systems	Internet of Things and augmented reality
Henao-Hernández et al. (2019)	Colombia	Data-driven decision making and manufacturing systems	Additive manufacturing
Bula et al. (2019)	Colombia	Modeling and manufacturing systems	Additive manufacturing

(continued)

Table 4 (continued)

References	Country	Name of the tool	Name of the technological field
Rossit et al. (2019)	Argentina	Cyber-physical systems and manufacturing systems	Additive manufacturing
Ponce et al. (2019)	Mexico	Modeling	Additive manufacturing
Garcia et al. (2018a)	Ecuador	Cyber-physical systems	Autonomous robots
Cruz et al. (2018)	Colombia and Venezuela	Cyber-physical systems	Autonomous robots
Mon et al. (2018)	Argentina	Manufacturing systems and IoT devices and systems	Internet of Things, big data and analytics, additive manufacturing
Salazar et al. (2018)	Argentinaand Ecuador	Sensor networks	Internet of Things and cloud computing
Garcia et al. (2018b)	Ecuador	Cyber-physical systems	Autonomous robots
Luna et al. (2018)	Peru and Uruguay	Modeling	Simulation
Velásquez et al. (2019)	Argentina	Cyber-physical systems and IoT devices and systems	Internet of Things
Ravina-Ripoll et al. (2019)	Mexico	Manufacturing systems	Additive manufacturing
Gil and Zapata-Madrigal (2019)	Colombia	Ontology instance management and modeling	Internet of Things
Vo et al. (2020)	Mexico	Manufacturing systems	Additive manufacturing

(continued)

Table 4 (continued)

References	Country	Name of the tool	Name of the technological field
Caiza et al. (2019)	Ecuador	Cyber-physical systems	Internet of Things
Jácome and Jácome (2019)	Ecuador	Cyber-physical systems and IoT devices and systems	Internet of Things
Hinojosa-Palafox et al. (2019)	Mexico	Cyber-physical systems	Internet of Things
Ravina-Ripoll et al. (2020)	Mexico	Manufacturing systems	Additive manufacturing
Neira et al. (2020)	Mexico	Modeling	Augmented reality
Estrin et al. (2020)	Argentina	IoT devices and systems	Internet of Things
Yamao and Lescano (2020)	Peru	Smart cities	Internet of Things
Arbulu et al. (2018)	Colombia	Sensor networks	Autonomous robots
Giorgio and Mon (2019)	Argentina	Human–machine interaction	Horizontal and vertical system integration
Rodríguez et al. (2018b)	Colombia	Modeling	Internet of Things and cloud computing
Rodríguez et al. (2018a)	Colombia	IoT devices and systems	Horizontal and vertical system integration IoT
Rodríguez et al. (2019a)	Mexico	Machine learning algorithms and modeling	Horizontal and vertical system integration
Rossit et al. (2020)	Argentina and Colombia	Modeling and data-driven decision making	Horizontal and vertical system integration
Sánchez et al. (2018)	Venezuela and Ecuador	Real-time processing	Cloud computing
Zamora et al. (2017)	Costa Rica	Machine learning algorithms and human–robot interaction	Horizontal and vertical system integration

Source The Authors (continue)

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Artificial Intelligence as a Support Philosophy for Change: Comunidad Andina Case Study

Ben Y. P. Yabar-Vega and Yvan F. Diaz-Zelada

Abstract The present study aims to observe the development of artificial intelligence in Bolivia, Colombia, Ecuador and Peru, countries that make up the Comunidad Andina, a supranational organization located in South America; likewise, understand the contribution of artificial intelligence as a philosophical component in the dynamics of change that are occurring in the different productive sectors of the aforementioned countries. In this sense, different sectors of each member country of the Comunidad Andina are analyzed. By inserting artificial intelligence in these four countries, it has been transforming reality in the different productive sectors through technology, self-learning and organizational knowledge, all this is modifying business and organizational paradigms, generating new ways of conceiving of companies. Economic organizations, understanding this as a new philosophical conception of organizations. This study uses the official reports and journalistic notes on the situation by productive sectors, issued by the competent government agencies and by the companies themselves, and based on the information collected, a comparative analysis is carried out between the countries that make up the Comunidad Andina, where the component "Economic model" is essential. The study finally aims to offer a basic document that serves as a diagnosis of artificial intelligence and how this variable has been transforming public thinking and policies aimed at the development of productive sectors and business conception.

Keywords Artificial Intelligence · Philosophy · Productive sectors · Comunidad Andina

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1 Introduction

Movement and change in the physical philosophy of the Presocratics. In the historical evolution of societies, the categories movement and change have been closely related and present in Western thought since the first moments of Greek philosophy. Thus in the words of Aristotle "Thales [of Miletus] thought that everything is full of gods" and "assumed that the soul was something capable of producing movement", interpreting, without anachronisms, god and soul as agents of movement from the first moments of western thought. Thales of Miletus was followed by Anaximander and Anaximenes. Anaximander imagined the *apeiron* and on this allusive term at the beginning of things, he thought that "that original mass was in incessant movement" (Guthrie, 2017, p. 36) and Anaximenes addressed the origin of things through the air, a concept that linked it to movement and change. In a piece of news about Anaximander's thought, Hippolytus mentions "the principle, that is, the element of beings is the indeterminate (being the first to use the name «principle») and that, in addition to this, there is an eternal movement in the one that happens that the heavens originate" (Bernabé, 2019, p. 70). And Anaximenes in the words of Theophrastus stated in the context of the *aér* as *arché* "regarding the movement by which the change also occurs, he makes it equally eternal" (Bernabé, 2019, p. 79).

Referring to change strictly and how it was imagined is also to reflect on what the philosophy of change has been and in that sense the Presocratics Heraclitus of Ephesus and Parmenides of Elea should be considered. About them Guthrie (2017) sentences "Parmenides was the exact opposite of Heraclitus. For him, movement and change were the only realities. For Parmenides, movement was impossible and the whole of reality consisted of a simple, immobile and immutable substance" (p. 57).

A famous fragment[1] by Heraclitus about the possibility of change has remained for posterity: "Different and different waters run over those who enter the same rivers" (Bernabé, 2019, p. 161). Also about Heraclitus and in the words of Dilthey (2018) "he places fire as the first living thing, but he elevated this way of considering things to the metaphysical awareness of the cosmic law of constant change and flow" (p. 33) and Parmenides about the impossibility of change, more extensive fragments of it are preserved, then an extract[2] related to the impossibility of movement and change is presented: "there is nothing and there will be nothing outside of what it is, for Fate has bound it to make it total and immobile" (Bernabé, 2019, 190–191).

Movement and change in the humanist philosophy of classical Greece. Now we move on to the thought of the philosophers of classical Greece. With the appearance of Socrates there is a turn in the thinking of the Greeks, in this regard Taylor (2016) refers "Socrates created the moral and intellectual tradition from which Europe has lived since then" (pp. 109–110). The Presocratic physical philosophers were displaced by the humanist-oriented philosophers, of the latter being their greatest representatives Plato and Aristotle. The former was strongly influenced by

[1] It corresponds to fragment 12 of Heraclitus of Ephesus, translated by Diels-Kranz (Bernabé, 2019, p. 161).

[2] Excerpt from fragment 8 of Parmenides de Elea, translated by Tarán (Bernabé, 2019, p. 161).

Heraclitus and Parmenides, which required him to reflect on the feasibility of knowledge based on the possibility and impossibility of change. Transferring the postulates of Heraclitus to the problem of knowledge, it could not exist as everything was in continuous flux and with respect to the postulates of Parmenides he had implied that "permanent reality exists, and that it can only be discovered by the activity of the mind, completely apart from the activity of the senses. The object of knowledge has to be immutable and eternal, free from time and change" (Guthrie, 2017, p. 100). With these antecedents Plato before the opposition postulates "He argued that the objects of knowledge, the things that can be defined, exist, but cannot be identified with anything in the perceptible world" (Guthrie, 2017, p. 101). This is how the "model" emerges in the form of an idea, but to refer to a model in that sense, Guthrie (2017) affirms "such are the famous "Platonic ideas", named after a transliteration of the Greek word "idea", which Plato applied to it, and which means model or pattern" (p. 101).

For Dilthey (2018) Plato systematized the knowledge of his time in "dialectics (discovery of ideas and their relationships), physics (construction of the cosmos of nature through ideas) and ethics (derivation of the principles to establish the cosmos of the society)" (p. 50). Another philosopher to consider contemporary of Plato was Democritus[3] who proposed the theory of atoms, which included the movement through atoms. Dilthey with respect to the theories of Plato and Democritus synthesizes:

> This theory of ideas represents the most genuine Greek national speculation, related by its character to Greek art friendly to the type and harmonious module, and which in its deduction, from autognosis, was victorious against the sophists and cynics. and in his reasoning based on the intelligible order of the stars and their movements against the atomists. At the height of Greek speculation we see that, alongside the mechanistic metaphysics of Democritus, the idealistic metaphysics of Plato. Between these two metaphysical systems the future would have the victory reserved for Democritus but, at that time, it could not offer a solution to the problem; The Platonic system prevailed in the explanation of nature, with the importance it attributed to psychic forces and metaphysical entities, since it was impossible, in the state of science of that time, an explanation by material forces (p. 50).

With Plato, it seems that the postulates of Parmenides are superimposed on those of Heraclitus and Democritus with the original conception of the Greek "ideai" or model, within the framework of a supersensible world where knowledge does not change, it is only identified. Years later Aristotle, his disciple, within the framework of humanist and metaphysical philosophy, also addresses the phenomenon of movement. Guthrie (2017) goes back in time and asks the following questions and answers at the same time:

> How to bring to the field of philosophical knowledge a world of variable phenomena, incessantly changing, that as soon as they exist as they do not exist, and that are never equal to themselves in two consecutive moments? Where is the stability that, as we saw at the beginning, the human mind demands? Aristotle's solution rests on two concepts related to

[3] Born in 460 BC and died in 370 BC. He is younger than Socrates, born in 470 BC and died in 399 BC, which is why he has not been considered in the previous section corresponding to the Presocratics, although he is usually considered in that group, as is the case of Alberto Bernabé.

each other and fundamental to his philosophy: a) the concept of immanent form and b) the concept of potentiality (dynamis) (p. 143).

Guthrie (2017) about Aristotle's immanent form refers to "the world seems to be in constant motion and does not offer fixed, unique truths that can be objects of scientific thought, however underneath it there are certain principles or basic elements that do not change" (pp. 143–144). And on potentiality Aristotle "felt so strongly the need to explain movement (…) that he defined natural objects by saying «that they contain in themselves the principle of movement and rest»" (p. 148). As a synthesis of Aristotle's thought, it can be said that the entity that generates movement and change in the different planes of reality is god, the Aristotelian god, however it goes beyond the metaphysical and also defined physical change or movement, as "the updating of the potential, insofar as it exists" (Pérez, 2012, p. 152).

The philosophy of change in the contemporary age. Before referring to the philosophy of change during the contemporary age, a quick look at the Middle Ages and Modern Ages as antecedents of the philosophy of change in the contemporary age should be taken. Medieval philosophy spans a thousand years, influenced from its beginnings by the Aristotelian tradition, Saint Augustine and John Damascene (Dilthey, 2018). It constitutes the zenith of medieval thought, scholasticism, a current of thought oriented to scientific providentialism. Likewise, despite corresponding to a world, where Christian dogma dominated, the influence of Plato and Aristotle was present in medieval scholasticism. Aristotle exerted a greater influence in the Christian world, especially in Saint Thomas Aquinas and the scholasticism of the full Middle Ages on movement and change from the perspective of cosmology (Beuchot, 2013), however Plato bequeathed the conception of the models of the supersensible world to the conception of the Christian God as the ideal model of the heavenly universe for the earth. Likewise, the existing change is an attitudinal-religious change from sinful man to virtuous man as a function of man's conversion to Christianity.

The modern age opens with the scientific revolution in the sixteenth century and "catapults" the natural sciences in the scientific work of that time, that is, the natural sciences are superimposed on the social sciences. Isaac Newton is probably the synthesis of the period with the laws of natural motion and universal gravitation, started with Aristotle and followed by Ptolemy, Copernicus, Galilei and Kepler. Newton published his famous Philosophia Naturalis Principia Mathematica where he brilliantly addresses the phenomenon of motion. It is important to indicate that the thinkers of the period are mainly "natural philosophers" of modernity (Pérez, 2012) and therefore the theories were oriented to the natural movement rather than to change as a socioeconomic phenomenon. Cohen (1994) develops a masterful fusion between Greek thought and the modern scientific revolution, excluding the medieval period:

> Looking back from the favorable position of the Scientific Revolution provisionally completed by the Newtonian synthesis, we first consider the various components of the Greek heritage. The little corner of mathematized science, located in a minor site of the legacy (of Greece), grew and was enormously transformed. On his way to providing rational mechanics and equally mathematical dynamics of the solar system, he shaped the universe of precision and prepared to transform his social and intellectual environment in turn and continue to do so to this day. Among its first and most obvious victims is natural philosophy,

> cultivated in an Aristotelian setting. During the Renaissance the cult of Aristotle had prevailed over a plurality of different rival views and had even regained vitality in the process. But it did not withstand the onslaught from the universe of precision. Despite the fact that some of the attacks against it were unjust, despite the tenacity of its roots in European universities, despite the eager search for mixed forms, in the end the Aristotelian cult did not resist the new universe (p. 514).

But to understand the current configuration of the philosophy of change, we must go back to the beginning of the contemporary age with Auguste Comte and his objective of generating a theory about progress based on order, this in a context where the lags of the era of violence and terror that were experienced in France and Europe by action of the French Revolution and the period of the Napoleonic wars, generated uncertainty to the ideal of development, Comte generated the law of the three states (theological, metaphysical and positive), according to which everything concept, branch of knowledge, or science passes through the indicated states (Pérez, 2012). The nineteenth century is characterized by the thought associated with evolution, historicism and political economy, where the category of change is very present.

Unlike the precepts of the French Revolution and the thought of Marx, Comte promoted more than change the improvement of society through the exercise of science and the positive state. His ideological adversary, Karl Marx, promoted change, through the theory of the struggle of opposites and dialectical and historical materialism. Dialectical materialism is probably the one that best serves us to explain the philosophy of nineteenth-century change. But before Mark "the utopian socialists Claude Henri de Saint-Simon, Robert Owen and Charles Fourier, (…) aspired to a gradual change of society" (Panty, 2015, p. 17).

The Comtian model of order and progress was imposed on the Marxist model of revolutionary change, which resulted in the triumph of capitalism over communism, and which allowed the development of industry and business, with the consequent dizzying generation of products and services. Services. Capitalism has fostered a new way of conceiving the world through postmodernism that "It prefers a relative time according to the social contexts, time that is ambiguous, reversible, random, incurring; a timeless time that the postmodernist sociologist Miguel Castells describes as a mixture of sequential times in the «network society»" (Panty, 2015, p. 67).

Postmodernism is a consequence of the capitalist system as is the globalization process, which is incessant and where technology plays a fundamental role. And from today's science, quantum physics, critical rationalism, complex thinking (Cruz et al., 2014) and the sciences of complexity guide scientific endeavor. All this has allowed the development of digital business, data science and artificial intelligence, which in turn have influenced the modification of the philosophy of change, initially present in the human being manufacturer and service provider for the human being the promoter of artificial systems provided with intelligence supported by computing.

2 The Context of the Fourth Industrial Revolution: Welcome, Artificial Intelligence

People associate artificial intelligence (AI) with robots in science fiction movies that display certain human characteristics and behave as such. But AI is not far from it; it is present in smaller individual components with which we interact every day, and we unknowingly use autocomplete functions when composing an email or when writing instant messages or ingesting social networks from a mobile phone, when we use electronic assistants or algorithms of search such as those used by Netflix or Spotify that decide what we want to see or hear, or when the yellow box appears every time we take a selfie, to more elaborate applications such as those used by autonomous vehicles or specialized equipment for medical diagnoses. In this context of technological development, the large companies in this sector have accelerated their improvement processes and the creation of new technology that will have a greater impact on our lives (WIPO, 2019).

We can define artificial intelligence as the simulation of human intelligence processes by machines, especially computer systems, which include learning, the acquisition of information and rules for the use of information and reasoning using the rules to reach conclusions approximate or definitive, with the intervention of a software that replicates human capacities for reasoning and analysis, either for specific tasks or for broader tasks that require a high degree of analysis and interpretation of information (Maureira, 2018, p. 143).

One of the first definitions for artificial intelligence was the one proposed by Alan Turing,[4] who was able to decipher the Nazi Enigma[5] machine. Turing was the first scientist to question whether machines could have the ability to think; For this, he proposed a method called "The Turing Test" with which he sought to verify if a human interacted, without knowing it, with a machine and was unable to distinguish if it was not a human (González, 2007). But the beginning of artificial intelligence as a discipline occurs at the Darmouth Conference,[6] where John McCarthy, Marvin Minsky and Claude Shannon coined the term and defined it as the science and ingenuity of making intelligent machines, especially calculation (Escolano et al., 2003). Today, these machines have more capacity than humans themselves to recognize patterns, something that has been very useful in fields such as research and disease prognosis. Despite this, they are still unable to learn associatively, as man does. A

[4] Alan Mathison Turing was a mathematician, considered one of the fathers of computing and a forerunner of computing.

[5] Enigma was the machine used by the German regime during WWII to send encrypted messages. The particularity of Enigma's encryption lies in pressing any key on the keyboard, the electromechanical system of the machine would send a completely different letter than the one that was pressed. This was generated thanks to the internal device that Enigma had made up of three rotors, which inside housed circuitry and wiring that made that when pressing a key, the internal system turns this pressed key into another completely different key, which made it practically impossible to be able to decode the messages generated with Enigma.

[6] Dartmouth University Conference in 1956. New Hampshire, USA.

child, for example, can see a dog and recognize it quickly, while a machine recognizes it after seeing billions of examples of dogs, and non-dogs. If we also want to teach him that the owner of the dog is Juan, we have to start over with the training, designing new algorithms.

Humans are capable of marking all the specific results in a larger set; we quickly recognize the dog and its owner and relate them. Algorithms may be very good at something, but only "something" is. Unlike machines, we are able to see a panorama and associate all our knowledge. In this context, machines have a long way to go. Navrina Singh, Microsoft's global leader in AI products, coined the acronym F.A.T.E, which contains qualities that should go hand in hand with AI research. F.A.T.E, refers to fairness, technology must be fair and not discriminate. There must be guarantees that it is treated with equality, accountability, it must be very clear to whom responsibility is attributed for the consequences of the use of information systems, transparency, it is very important that it is legible and that It is explained in non-technical terms, so that it can be understood by an average citizen, who must be able to understand how the systems that are being created thanks to AI work, as well as understand the types of data that are being used and how they are using them, among other things and ethics (ethics), it must be ensured that the use and application of the systems and their development are in accordance with the set of ethical values and principles that as a society we respect and accept (Cotino, 2019).

Society has conflicting opinions regarding artificial intelligence. For many, it is a constant concern that AI has the ability to make decisions that put people's lives at risk or that could rebel against man, although this is highly unlikely. However, there are other reasons that should be reasons for reflection on how to counteract the consequences that they will bring due to the sources of work that will be lost day by day due to the growing implementation of these technologies. The first massive job losses occurred during the Industrial Revolution in 1760 when machines replaced many of the physical jobs. With this new Industrial Revolution, called the Fourth Industrial Revolution, physical jobs continue to be lost due to the capabilities of new robots to assemble all kinds of products and do activities that are initially designed for the person. But the biggest job losses that are occurring in companies are those that are related to the mental, intellectual and reasoning capacity of the human being, rather than with the physical part of the person (Matas, 2019).

3 How Artificial Intelligence Works

AI works thanks to the integration of several integrated processes that make it possible to carry out specific activities. For this, it is required to design robust algorithms capable of obtaining and processing information in a similar way to the human brain, making direct use of information available from the internet or perceiving facts or events from the environment that surrounds them, with the help of peripherals or devices such as cameras. Microphones, motion sensors, proximity or any other device that allows the system to collect data from the environment (Garrido, 2020).

For the operation of AI, computers must be trained by man to search and identify information, and for this, modalities such as robotics, machine learning or cognitive intelligence provide different solutions. Machine Learning is the best known branch of AI. This is a technique that helps computers learn by repetition through patterns that track millions of data. It is a statistical type of learning that helps to predict future behaviors. Machines improve by continuously acquiring wisdom without human intervention (Garrido, 2020).

Cognitive intelligence is a more advanced scenario that evolves methods based on statistical learning. Machines are endowed with millions of definitions, concepts, slogans and relationships so that they learn the context of language and understand the meaning of words. Computers read this information but also learn to understand, interpret and reason it, providing strategic value for decision-making. Let's analyze the following example. The human brain clearly visualizes an animal and a vehicle and can differentiate between them. With statistical learning, a machine loses nuances, so it will be difficult for you to clearly determine whether it is a vehicle or an animal, and this is because it lacks the context of the information that has been provided. Cognitive intelligence, by understanding the context, will know how to quickly discern between a jaguar that walks through the jungle and a jaguar[7] that circulates on a city street. Technologies such as Cogito from Expert System,[8] help companies to interpret, reason about the information acquired and answer the user's needs and with this simulates the process that the human mind executes when it receives and reads new information, working daily reading and interpreting information worldwide in more than fourteen languages with a 98% accuracy rate. In this case, the software is taught so that once the operations of a business are transmitted, it can operate autonomously and without errors, 24 h a day, 365 days a year. This new Industrial Revolution is changing the way the company makes decisions, but above all, it is migrating the way companies think and analyze information to make decisions without human intervention. This philosophical paradigm confronts the man of yesterday and the man of today and tomorrow and how this paradigm generates changes in society, economy and business (Lahoz-Beltrá, 2012).

4 Challenges and Advances of AI in the World

By definition, artificial intelligence (AI) is a program, a mixture of hardware and software, that has been designed to replace the human being in the activities of

[7] In this context the author refers to the "jaguar", in two different contexts. The first one refers to the animal that runs free in a jungle, while in the second scenario it refers to the English luxury car brand Jaguar Cars that is part of Jaguar Land Rover.

[8] Cogito Studio is a fully integrated development environment used to design and implement AI-based text analysis models that take advantage of the cognitive capabilities of the Cogito platform. As the powerhouse of all Cogito-based developments, Cogito Studio helps organizations and developers create unique and advanced solutions to expand the scope of automation of intelligence processes and increase the efficiency of finding and obtaining knowledge. Taken from: expertsystem.com.

a human intelligence. Under this definition we could conceive of a calculator or a personal computer as AI. But for this meaning to have a full meaning, it is necessary to speak of cognition that gives rise to the term cognitive intelligence. Cognition as such is a more elaborate analysis process, and it is the ability of the human being to process information that it captures through the senses. Memory, language, comprehension, orientation or reasoning are examples of cognitive abilities (Adarraga & Zaccagnini, 1988).

A Canadian startup from the University of Toronto in cooperation with International Business Machines Corporation (IBM) and with the help of the supercomputer Watson, developed Ross, the first robot lawyer that can litigate with the help of AI. Ross is able to listen to the litigating parties and review more than 10,000 pages per second so he can give an answer 1000 times faster than a human lawyer. AI projects like Ross would help law firms with virtual assistants who answer basic client inquiries (Almonacid & Coronel, 2020).

AI has also had a strong impact on the automotive industry. The technology is present from the creation of the vehicle, through its use, the recognition of the driver and even commercial processes with insurance companies. The most important AI development in vehicles has been in driver assistance to fully autonomous vehicles such as Tesla's Autopilot,[9] which thanks to Google's Waymo has managed to add thousands of kilometers of real autonomous driving tests—unassisted. This driving without human intervention is produced with the help of different cameras and sensors distributed inside and outside the vehicle, which control, among other things, the driver's fatigue, the contours of the lanes in case the vehicle leaves the road, automatic braking that considers time conditions (light-dark), speed, pedestrians, obstacles, curves, slopes, among other aspects (Tesla, 2020).

5 The Development of Artificial Intelligence in Colombia

Colombia is the fourth largest economy in Latin America,[10] with a GDP of US $ 264,933 according to the report published in 2020 by the International Monetary Fund (IMF). On August 5, 2020, IBM inaugurated in Colombia, the Centro Cognitivo de Transformación, the largest center for process information with artificial intelligence of IMB in Latin America. From this center, based in Bogotá, it manages more than 14 million invoices, 7 million monthly operations, 700 thousand call center calls per month, and attention to more than 60 thousand complaints from clients of different companies in areas such as purchases, finance, reading, invoice collection and back office management.[11]

[9] Tesla Autopilot is an intelligent vehicle that accelerates and brakes autonomously. The most significant progress that Tesla has made is that the vehicle can stay within its lane while it "self-maneuvers" thanks to self-learning provided by AI. Retrieved from www.tesla.com/autopilot.

[10] "Report for Selected Countries and Subjects" dated February 19, 2020.

[11] Report published in August 2020 by the state promotion agency ProColombia.

Before the arrival of IBM's Cognitive Transformation Center, Colombia had been developing minor AI projects, mainly applied to the services sector. At the beginning of December 2020, the Presidency of the Republic launched the initiative of the ethical and legal framework for artificial intelligence for this country (IMF, 2020). As a result of these two advances, the sector that has shown the greatest development in AI issues has been banking. 63% of the crimes that occur to these Colombian companies are committed by their own employees, which shows that indistinctly all companies are at risk of fraud and although they protect themselves from external threats, they must learn to mitigate the internal risk associated with the conduct. Of his collaborators (Rincón et al., 2015). In this context, Colombia has been applying techniques such as "machine learning" or other techniques in the identification and resolution of patterns and in prospective analysis, with which it is trying to identify the biases that occur in security processes and give them greater speed with more homogeneous precision, avoiding the biases of conventional (human) analysts when grading a person's risk. (Gonzalez, 2020).

This is how Colombia begins the development of its project called Predicto, which uses artificial intelligence to detect fraud attempts and autonomously monitor security processes. Predicto was initially born as an application to control the recruitment phase in which companies evaluate their candidates. Its appearance was quite controversial since it could be considered a kind of advanced polygraph, since the first component of the software what it does is a physiological evaluation in which different hardware devices that use AI are integrated, an eye tracking system that analyzes rainfall changes and archaic eye movements, thermographic information that analyzes how the blood flows in the face and even the way the subject breathes without physical contact with the face and a galvanic evaluation of the skin that analyzes the changes in the microvoltages that occur on the skin, as well as alterations in heart rate. Currently Predict has a 90% accuracy to interpret whether or not a person could be misleading when it comes to answering certain questions. Predicto is trained with machine learning, so it is trained with the information of thousands of counterfeiting crimes committed in different circumstances with which it learns from itself to easily detect, and in a very short time, the symptoms physical characteristics of a person when he lies. For some experts, the software constitutes an invasive technology, while for developers Predicto is a solution initiative to attack corruption that is one of the problems that most affects Latin American countries. This has been one of the greatest advances that Colombia has had in AI issues (Rincon et al., 2015).

6 Bolivia Facing the Fourth Industrial Revolution

In his 2020 book "A 4.0 Strategy for Artificial Intelligence in Bolivia", Gissel Velarde analyzes the Fourth Industrial Revolution as a strategy that Bolivian companies must develop in the face of global technological development which he calls "Digital Cataclysm", which will have its maximum peak in the next 20 years and that has been impacting the business processes of many world-class companies. Within this scenario of transformative forces for change, many Bolivian industrial sectors hope that this new revolution will have a significant and positive impact due to factors that are gaining strength in this country, such as the existence of a growing virtual, autonomous workforce and the development of technological intelligence in recent years. Many Bolivian companies are betting that in the future Bolivian labor will not be required, but rather it will be replaced by specialized autonomous machines, and with this it is expected that workers will be 40% more productive than at present, which could be seen reflected in that the effective work of a person would decrease from a day to noon or perhaps a few hours. The amount of inventions and innovations in AI in Bolivia will open new income streams generating economic growth. According to a report published by Pwc UK in 2017, this growth would cause an increase in world GDP of 15.7 trillion dollars by 2030 (Pwc, 2017).

Los desafíos que debe enfrentar Bolivia en aspectos tecnológicos vienen fuertemente marcados por una dura competencia internacional con fuertes inversiones en desarrollo tecnológico como es el caso de Singapur con 9.2 millones, seguido del Reino Unido con 9.1 millones destinados al desarrollo y Alemania con 8.8 millones. Latinoamérica, muy relegada del resto del mundo, y Bolivia en el puesto 89 con 4.4 millones en las 154 economías mundiales incluidas en el Ranking Mundial de Países pro Inteligencia Artificial (IA LATAM, 2020).

The challenges that Bolivia must face in technological aspects are strongly marked by tough international competition with strong investments in technological development, such as Singapore with 9.2 million, followed by the UK with 9.1 million for development and Germany with 8.8 million. Latin America, highly relegated to the rest of the world, and Bolivia in 89th place with 4.4 million in the 154 world economies included in the World Ranking of Artificial Intelligence Countries (IA LATAM, 2020).[12]

Another challenge that Bolivia faces is the generation and retention of human talent, since the few professionals who are trained or specialize in technology and information sciences, choose to leave the country given the low valuation that is given to their professional effort, finding better opportunities in foreign countries such as Argentina, which in 2019 received 426,394 Bolivians, Spain, which gave the job opportunity to more than 151,235 professionals, followed by the USA with 93,443 Bolivians (UN, 2019). The Bolivian state is developing strategies to attract and attract foreign professionals to promote large-scale development in AI issues. Although professionals do not show a sensitivity to remuneration, they do give a higher value to the possibility of receiving the responsibility of directing AI development laboratories with a very dynamic ecosystem that allows them to carry out research in this field. One of the latest projects of this magnitude is a Swedish-Bolivian pilot that was implemented at the beginning of 2020 at the El Alto de La Paz international airport, based on artificial intelligence that allowed measuring temperature and recognizing

[12] The world ranking of countries pro Artificial Intelligence, is published by IA Latam, which considers 194 world economies. Taken from: https://ia-latam.com/2019/08/19/ranking-mundial-de-paises-pro-inteligencia-artificial/.

patterns and symptoms to identify and prevent COVID-19 infections in passengers entering through this air terminal (Anadolu Agency, 2020).

7 Ecuador and the Discovery of Artificial Intelligence

In the research developed by López González and Baquerizo Orrala, entitled "Management of electronic money in Ecuador and its incidence of the transfer to private banking", the authors present a definition that is still known in the Republic of Ecuador and is related to the area of cognitive learning applied to safety. The banking sector in Ecuador has started the implementation of cognitive banking progressively, and this has constituted one of the pillars of the vision of exponential banking, which is nothing more than achieving the development of automated banking or augmented banking or open banking. This sector has been taking advantage of artificial intelligence to improve in many aspects the financial industry that for years has moved solely by intuition toward a more scientific part based on the data itself, taking advantage of the large volume of data that this sector generates. Workers in the financial sector have developed over the years and experience the ability to read safely, and with great dexterity, large amounts of figures and digits, but they have also developed the ability to see, listen and speak strategically. Even being able to predict based on the events they have experienced in the past, these tasks and actions have been replaced thanks to the implementation of cognitive technologies, which are giving traditional banking, to do all this through a computer with great efficiency, at scale, in real time and with a high degree of security and reliability (López and Baquerizo, 2018).

Following López and Baquerizo (2018), the objective sought by cognitive banking in Ecuador is efficiency, creating new conveniences, for the bank itself, as well as for the end customer, as well as the creation of new products and services. In contrast to traditional banking, which relied heavily on processes based on the intuition of the people who managed systems based on rules or very fixed parameters, what allows cognitive banking to take full advantage of these new technologies and management of large volumes of data that manage the bank, to generate many areas within the institution, for example, the power provider assistance 24/7 through chatbot, improve the operational efficiency of many processes, which are based on manual processing of many documents, and even open the minds of developers of financial products and services for the creation of new proposals based on the handling of large volumes of data. The authors conclude that entering the world of cognitive banking is not easy and implies that institutions in this sector incorporate, as part of their transformation and digitization processes, the adoption of exponential technology such as cognitive banking, which can be applied, within other uses, to the processing and classification of documents and extraction of entities, a task that is typical in banking who manage a large volume of documents such as legal claims, mortgages, account opening documents, emails, messages Swift,[13] call center requests; where many of these documents are currently processed manually. What artificial intelligence proposes through cognitive banking is to carry out these tasks through intelligent systems in a much more efficient, faster way, but the two most relevant aspects of these new technologies are the significant cost reduction and reduction of human error.

The development of chatbot as an implementation of cognitive intelligence applied to different Ecuadorian sectors has played a decisive role in the speed of attention, not only to end customers of commercial companies such as banking, retail or telecommunications companies that offer 24/7 assistance, but also it has become the support of companies whose users require access to information on products, services or processes, or carry out financial operations such as checking balances, making transfers to contacts, among other options. It is also possible to make use of systems that are capable of recognizing images to create new experiences, such as, for example, what would be the total cost of acquiring a new vehicle, for which the consumer must include in costs such as insurance, fuel that it would be used monthly, taxes, maintenance, tire change, among other aspects to consider. Cognitive intelligence enables the consumer to have a shopping experience through a mobile device that allows them to obtain all this information easily and quickly. Within this context, it is that different Ecuadorian companies in sectors such as the automotive, financial, banking, and even department stores, have been taking advantage of all the information they have or that they can acquire in digital channels to improve prediction and performance. Recommendation of products and services for their end customers in order to allow them to meet their life demands. This new era of hyper personalization that Ecuador seeks to achieve with the implementation of artificial intelligence, cognitive technologies allow specific companies such as banking to go beyond the traditional borders of banking such as the one known today, entering a real era where customers are increasingly demanding (Arteaga et al., 2019).

In the research carried out by Sardis Mosquera entitled "The link between artificial intelligence and cybersecurity in Ecuador. Notes on a necessary interconnection" analyzes how an expanding sector given that innovation in technology has drastically changed the way clients are managed, which for more than 40 years has constituted the very essence of the banking business in Ecuador, that entails challenges very new and unexpected for conventional banking supervisors and decision makers. Thus, artificial intelligence and development based on artificial intelligence force entities to adapt to this new circumstance or else they would be destined to disappear in the medium term. But artificial intelligence is not an issue alien to Ecuador, this concept began in the country in the 1950s where the need to discover new ways of doing things faster and more efficiently, forced scientists and researchers to develop new ways of doing things reducing the margins of error. In this sense, robotics has emerged

[13] SWIFT (Society for World Interbank Financial Telecommunication). Acronym that allows identifying financial and banking institutions at an international level. This code is normally used to carry out operations such as transfers, money orders or money transfers between financial institutions at an international level.

as a solution to address these problems, so this branch of artificial intelligence has entered the manufacturing industry with great force with fully automated factories that assemble and manufacture vehicles, the same processors that carry the computers inside, medical diagnostics and robots that perform sutures in human beings, up to 3D printers capable of printing bridges and entire buildings, printing each of the components that are then assembled (Mosquera, 2021).

8 The Reality of Artificial Intelligence in Peru

In this context, in Peru there are many companies that have been applying AI in their business processes. But the sectors with the greatest development and investment are banking, the retail sector and mobile phone companies. The most common implementations are found in areas such as customer service, where the use of chatbot-type applications are helping to attend more efficiently and at the lowest possible cost, basic customer inquiries and claims, as is the case of "Clara", virtual assistant implemented by Banco de Crédito (BCP) and jointly developed by IBM Watson. The IBM bot for the BCP is capable of handling basic operations such as balance inquiries, movements and basic information of credit and debit cards such as payment date, amount to be paid, exchange rate, interbank code inquiries and even more inquiries structured as a general explanation of the composition of an account statement, debt rescheduling, debt freezing or refinancing, types of insurance or banking products that a client could access, among other functionalities. At present, IBM's Watson is the company that has developed the most AI implementations in Peru and Latin America, precisely with the generation of these virtual chats or "chatbots" that replace conventional call centers with an assistant generated by intelligent technology. The "bots" are a very simple technology to train, which is why it represents an interesting starting point for Peruvian companies that have decided to implement AI to their business processes (BCP, 2020).

Another sector where AI has been developed in Peru is Health. IBM Watson and the Ministry of Development and Social Inclusion (MIDIS) in 2018 developed an AI-based program to combat anemia in children under three years of age, for which Watson was trained in reading documents and reviewing information that allowed him the software understand the data available on the Internet, in articles, files, texts, reports and even in the information of the agents involved in this project. The "bot" is trained to read as a real human does and abstracts the content, concepts and definitions of interest and relates them to the problem that the project wishes to address. This training was carried out by agents and companies who had to train Watson in reading and reviewing the information. When the "bot" learns to read, the search for information is carried out in fractions of a second, obtaining much more precise and faster answers (MIDIS, 2018).

9 Discussion and Conclusion

As aspects to be discussed in this article, first it has been found that the philosophy about change in the Western world has been present since ancient times; and "change" through the various streams of thought has been considered favorable to humanity. Likewise, from the historical perspective, the discipline of AI began in the middle of the twentieth century with important advances in the so-called developed countries, but with a lesser presence of these new technologies in the so-called third world or "developing countries". Development", that is, AI is associated with countries that are intensive and extensive in technology development and also with countries that promote private investment. Regarding the Andean Community, although it is evident that in the four countries belonging to this bloc, the private sector together with the State are working and promoting AI, it seems that it is correlated with the economic model, the two countries that advanced the most in AI it is Colombia and Peru, which present more liberal economies, while Bolivia and Ecuador with more planning economies, present less development in this field.

As a conclusion, it can be considered that change is inherent to man and his societies, as has been shown philosophically and historically, however the economic condition of each country will promote or stall AI. In this sense, the countries that make up the Andean Community, whose companies are developing AI, and in which its promotion by their States is observed, have a great challenge in the opportunity that means betting on AI, since it brings economic returns, however, its development will be conditioned by the sustainable continuation of policies that favor it and that are based on the economic model practiced by each country.

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Mining Pre-Grade Academic and Demographic Data to Predict University Dropout

Álvaro Martínez-Navarro, Elena Verdú, and Pablo Moreno-Ger

Abstract Digital transformation is enabling institutions to enhance their processes by using data and technology. In education, digital transformation allows improving the learning experience as well as the institution processes. Within education 4.0, artificial intelligence applied to learning analytics is playing a key role for universities, particularly in the dropout issue, especially in STEM with the highest dropout rates. This is particularly relevant in the Latin American Higher Education scope, given the low labour productivity in these countries. In these countries, universities often have more demand than supply, and achieving an adequate balance between admission rates and dropout rates is a key issue. A high dropout rate harms the prestige of the university and damages students who were admitted without being adequate candidates. Understanding why students abandon their studies help to know what a university can do to avoid it. Data mining (DM) techniques can help discover the individual features that influence the dropout. There are different studies proposing models to predict dropout, and most are based on data that are not at the admission stage. We propose an approach that uses DM techniques to predict dropout based on data at the admission stage. We discover factors influencing dropout by a decision tree and association rules. We use a dataset of students of a computer science degree from a University in South America and achieve good performance when predicting dropout. The most attributes influencing dropout are the pre-grade performance in STEM subjects and the location of the city of residence.

Keywords Digital transformation · Decision trees · Machine learning · Predictive models · Computer science education

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1 Introduction

The twenty-first century has brought a global transfer of socio-economic relationships to the digital world, which is termed as digital transformation (DT) (Mikheev et al., 2021). To remain competitive companies must shift to digital technologies, with special emphasis in safe connectivity, big data, Internet of Things and wearable technologies. Industry 4.0 has been impacting many disciplinary fields such as medicine, agriculture, manufacturing and lately education. In education, DT means an evolution in teaching and an adaptation to the new learning needs, as well as an opportunity to widen the educational coverage and productivity of education institutions (Abad-Segura et al., 2020). The term Education 4.0, understood as the training that includes an interactive presence of the actors of the learning process through technology (Ciolacu et al., 2017), has already been coined, and its development is taking place thanks to technologies. Specifically, big data and artificial intelligence are being adopted as educational resources to add value to complex issues in higher education institutions (Abad-Segura et al., 2020). In fact, a strong field growing is learning analytics, Ferguson et al. (2016) project this discipline to 2025 in eight scenarios. The sixth scenario talks about how analytics will become an essential management tool because predictions made with a degree of precision will allow managers to anticipate the success or failure of student learning and make appropriate decisions to maximize both efforts and resources.

The above situation becomes complex with novice students, in this sense, a growing concern of universities is to achieve an adequate balance between admission rates and dropout rates. While increasing enrolment implies more revenues in the short term, it also may increase the number of students who are unlikely to complete their degrees. This is especially relevant for STEM studies, which have a low level of retention compared to social science studies (Arias Ortiz & Dehon, 2013; Engström, 2018; García-Ros et al., 2018). In fact, the studies about desertion in STEM have been growing mainly because the dropout rates in these fields are higher compared to other disciplines (Kiss et al., 2019). A high dropout rate harms the prestige of the university, and, more important, it suggests that students are not well prepared to study what they selected. In many countries, stakeholders are paying attention to the low enrolment to university degrees in STEM areas, with internal political pressures to improve student performance and the low scores of students in national/international assessments (Ritz & Fan, 2015). This is an important problem. Specifically, the low labour productivity in Latin America and the Caribbean countries is given by the poor-quality education in these countries, according to the 2020 World Bank Report. Low performance in standardized tests, high dropout rates and unequal incomes prove their low-quality education (Mendoza, 2020).

Educational institutions store huge volumes of students' data such as enrolment data, test results as well as their interactions with the online institutional systems. The rapid growth of data and their potential to hold valuable information has led to the appearance of educational data mining (EDM) as a research and development field (Dutt et al., 2017). Both educational data mining and above-mentioned learning analytics target data-intensive approaches to education research to enhance educational practice, but there are several differences that can be found in the study of Baker and Inventado (2014). Through digital transformation, by incorporating educational data mining (EDM) techniques, universities can discover those individual features in their students and in their specific grades and processes that influence the dropout rate. Understanding why students abandon their studies is a first step towards figuring out how to avoid it.

With the objective of preventing high dropout rates, there are statistical studies finding out the characteristics of students who are at risk. García-Ros et al. (2018) analyse the relations among academic success and different pre-university variables (gender, entrance age, entrance grade, preference for studies, first-generation students), as well as social and academic experiences during the first year of university of engineering students. First-year academic achievement and institutional commitment are the best predictors of student retention. A more general study (Arias Ortiz & Dehon, 2013), compiling data from newly enrolled students in both STEM and social sciences studies, finds gender, nationality, socio-economic background or having a strong mathematical profile, as predictors of the probability of dropping out.

Within the EDM field, Nasiri et al. (2012) use regression and classification techniques, specifically C5.0 algorithm, to construct decision trees, to implement a model that predicts academic dismissal and grade point average (GPA) of graduated students. As inputs, they consider grades during semesters, passed and failed courses, as well as nationality and age demographic variables. Meedech et al. (2016) use decision trees and rule induction models to predict dropout among first-year students considering a collection of attributes related to student's academic performance in the first semester, student social behaviour, personal and education background. According to the obtained models the most discriminative attributes are the overall academic evaluation as well as the amount of grade F obtained at the end of the first semester. Chung and Lee (2019) also use decision trees (random forests model) to early identify students at risk of dropping out by taking into account their behaviour during the first month of the course. The variables more important to predict dropout were unauthorized absence, lateness and early leave, time of self-regulated activity and career development.

A clustering approach is proposed by Iam-On and Boongoen (2017). They consider two problem contexts: (i) during university admission, when only demographic and high-school academic data are available, and (ii) after the first year when initial university performance data are also available. In both cases, two groups are generated, and those students with good school academic background still perform well during the first university year, while most of those with poor school academic background dropout. Sarra et al. (2018) use a latent class model, the Bayesian profile regression, to discover typical profiles of students enrolled in a first-level degree course. The students of the cluster linked to a lower risk of dropping out are more satisfied and resilient, experiencing less difficulties during academic life, while they find the opposite characteristics for the students in the cluster corresponding to the highest dropout risk, who perform worse academically and are less satisfied with the educational experience. The dropout risk is measured from the intentions to drop out stated by students in a survey. Gil Vera (2017) proposes a dropout predictive model based on multivariate statistical techniques, factorial analysis and logistic regression. He considers sociodemographic variables (age, gender and socio-economic level) and variables related to the use of a virtual platform as interactions in forums, delivery of tasks, access to resources, etc. He finds out that the messaging teacher–student is a determining factor. In this line, Viloria and Pineda Lezama (2019), who use a mixture structural equation model, find that the interpersonal relationships and class attendance influence positively to college adaptation.

All these findings are useful for university staff to take measures to decrease dropout rates. However, it becomes evident that the most effective factors to predict dropout are those that can be collected in the time after the student has enrolled, so they are not useful to the predicting dropout risk during the admission period.

Some studies use data collected from questionnaires to investigate factors influencing students' failure (García-Ros et al., 2018; Hamoud et al., 2018; Lange et al., 2018; Pappas et al., 2016; Salamonson et al., 2016; Sarra et al., 2018). Others consider recorded academic data such as university grades (Iam-On & Boongoen, 2017; Meedech, Iam-On & Boongoen, 2016) or users' interactions with the institutional system (Lange et al., 2018). A common fact in these studies is that, when personal background is considered, it is limited to a few factors such as gender, age or region of residence. Therefore, the use of demographic data is generally scarce, although it may provide additional insights about factors influencing student dropout as Iam-On and Boongoen (2017) suggest. Moreover, the study of Arias Ortiz and Dehon (2013), who use a dataset merging the university's administrative dataset with the results of a survey filled in by students, find factors of the students' socio-economical background influencing on the success achieving graduation, such as the level of studies of mothers. If fact, another study (Engström, 2018) suggests that success can be connected to social background and parental levels of education, particularly for female students.

In summary, most of these studies consider data collected once the university course has started or used instruments to collect data that are not easy to implement in the pre-grade period.

Therefore, in this research we use EDM techniques and a dataset of students of computer science engineering from a university in South America with two objectives: to discover factors influencing students' failure and to build a dropout predictor by using student data typically available during the admission period. Demographic data (e.g. civil status, financial situation, family income, family members' education, etc.) and background school results are considered for the analysis. All data are collected from an institutional database and structured as a usable dataset after the anonymization of the data and a clean-up process to remove unusable records. The resulting dataset contains academic and demographic data that can be mined during the enrolment period, as well as an attribute indicating whether the students eventually abandoned their studies. This dataset is used to train a predictive model which yields high prediction rates using only these data.

2 Materials and Methods

The focus of our research is on the potential of using data mining methods to build a model to predict the student dropouts in the computer science degree of a Latin American University, with special emphasis on data available during the admission period. The experimental design of our study is similar to the one proposed in Martínez-Navarro & Moreno-Ger (2018). Firstly, an experimental platform was set up, including the needed software. Then, the predictive model was built by testing machine learning supervised techniques. The additional application of unsupervised methods allowed a deeper analysis of factors influencing the dropout rates. Specifically, the steps taken in all the process were (1) building and cleaning the input dataset, (2) preparation of the training and testing datasets, (3) training and evaluating the model, (4) fine-tuning the model and (5) further analysis through association rules.

2.1 Experimental Platform

A software platform was created to implement the experiment, with two main objectives: to facilitate data management/manipulation and to create and test the predictive model. The back end is based on an Oracle 10 g database management system that supports the University's admission system. The data from the backend were extracted and anonymized to create the comma-separated values (CSV) that were used as inputs for training and validating the models.

The model was created using the R open-source platform and the R Studio development environment. Different open-source R libraries were also used to develop the software platform that supports the study: **rpart,** employed to train and evaluate decision tree models; **rpart.plot**, used for creating visualizations of the models created with the rpart library; **Rattle and RGtk2**, Rattle was used to create a graphical user interface for the project, while RGtk2 is a required library to create Gtk interfaces in R; **arules** used for representing, manipulating and analysing data, frequent element patterns and association rules; and **arulesViz and grid**, arulesViz was used to create simple and interactive visualizations for association rules and item sets, while grid is a required library for controlling the appearance of the charts.

2.2 Building the Predictive Model

The predictive model was constructed using decision trees given their suitability for making the best decisions based on existing information in an input dataset, as well as providing data to quantify the cost of a result and the probability that it will happen. This means that the resulting model minimizes the number of attributes required to reach the decision or conclusion. The main reason why we chose this family of algorithms was that they allow addressing a problem such a way that all the solution options are analysed, and they are very easy to interpret (Rokach & Maimon, 2005). Moreover, previous related research reports good performance using these techniques (Chung & Lee, 2019; Meedech et al., 2016), and they allow to handle heterogeneous data (qualitative and quantitative) very well and control over-fitting through pruning processes (Baker, 2010). The preparation of the dataset and the model training process were performed through four specific steps, and then an additional analysis through association rules was carried out.

2.2.1 Building and Cleaning the Input Dataset

An important challenge when building an academic dataset is that, often, the academic information of students generated and stored in the institutional systems is not trivial to use given the differences in terms of technology and purposes of use (Swan, 2016).

Our study considered, in addition to academic information, the use of demographic data to provide additional information on the possible factors that influence dropout. The data were obtained from the university databases and properly anonymized to prevent the identification of individual students during our study.

In our experiment, we chose data from students from all periods of the computer science degree from 2010 to 2017, and the data were arranged so that each row would represent all the information available for a specific (anonymized) student.

In order to improve the quality of the dataset, the raw data were pre-processed through different tasks including the discretization of the geographic data (department and city of origin) to three possible values, LOCAL (city or department—where the university works), NEIGHBOUR (city or department–limiting the city or department—where the university operates) and EXTERNAL (city or department–outside the city or department where the university operates); the removal of non-relevant variables; and the aggregation of individual scores obtained in the national baccalaureate tests into subject–matter grades.

After cleaning up the data, the resulting dataset had 274 rows with 14 variables including the main attribute to be predicted: whether the student dropped out. The dataset included 146 (53.28%) instances of the students who did not dropout (NO) and 128 (46.72%) instances of students who did dropout (YES). Table 1 describes each of the variables in the input dataset.

2.2.2 Preparation of Training and Test Datasets

Following common patterns in machine learning projects, we divided the input dataset into several datasets in order to create or train the model and test it. There are two common approaches for this: divide in training, validation and test data or simply in training and test data (Borovicka et al., 2012). Given the size of the dataset,

Table 1 Variables included in the work dataset

Field	Data type	Description
Residence_city	String	Discretized residence of the student
Socioeconomic_level	Integer	Socio-economic level reported by the students in the admission process
Civil_status	String	Civil status of the students upon enrolment at the university
Age	Integer	Actual age of the students (derived from their registered birth date)
State	String	State of origin of the students (where they were born)
Province	String	Province of origin of the students (where they were born)
Vulnerable_group	Integer	Vulnerability code reported by the students on enrolment
Desired_program	String	Name of the degree pursued by the students
Family_income	Integer	Average income reported by the students' families
Father_level	String	Maximum level of studies of the male parent
Mother_level	String	Maximum level of studies of the female parent
STEM_subjects	Float	Average national baccalaureate test score for STEM subjects
H_subjects	Float	Average national baccalaureate test score for other (social science) subjects
Dropout	String	Whether the student dropped out

we used the second approach and tested two possible proportions: 80–20 and 66–34, achieving better results with the 80–20 proportion, which was kept for the study.

The observations included in each dataset were taken at random in such a way that in both datasets the percentage of instances with both values of the class are similar (Reitermanová, 2010). The values for our case differ, for the two classes, in 0.0069739, a very small value that assures balance in the observations of our training and test datasets.

2.2.3 Training and Evaluating the Model

The model was built with the traditional algorithm that is implemented in R's rpart library and acts in a similar way to the CART and ID3/C4 algorithms (Therneau et al., 2018). In this study, we distinguish two classes to predict: positive and negative. Positive class refers to those instances in which the value of dropout is YES, while negative class corresponds to students whose dropout value is NO.

We used different metrics to evaluate the performance of the predictions, focusing on TP rate (proportion of positive cases that were correctly classified), TN rate (proportion of negative cases that were correctly classified), precision in the prediction of each class (proportions of positive and negative cases predicted that were correct), accuracy (ACC) of the model (proportion of the total number of predictions that were correctly classified) and the confusion matrix showing the true results against the predicted results (Borovicka et al., 2012).

The model obtained was also checked through the graphical metrics of performance evaluation receiver operator characteristic (ROC) and sensitivity–specificity. The first compares FP rate with TP rate in a curve drawn between these two values; a better model will be the one with a value of area under curve (AUC) close to 1 which is the perfect prediction (Ting, 2011). The second one represents the sensitivity (TP rate, also called recall) against the specificity (TN rate), the perfect prediction in this measurement occurs when both converge in 1, that is to say they form a right angle in the upper right corner of the plane (Ting, 2011).

2.2.4 Fine-Tuning the Model

With the default values of the chosen algorithm, the first model was created, and its performance was evaluated with the metrics described in the previous section. However, the configuration of the model is very relevant, and we opted for systematic empirical tests to discover the best configuration for the input data.

The attributes that were empirically tested include min split (minimum number of observations that must exist in the node before a division is made), min bucket (minimum number of observations allowed in any leaf node, the usual value is the third part of min split), max depth (maximum depth), complexity-CP (which controls the size of the tree) and prior (probability of importance of each class).

2.2.5 Further Analysis Through Association Rules

For additional analysis of factors influencing dropout, association rules were generated by using aRules R library. Association rules allow to detect hidden relationships and correlations of data attributes (Benhacine et al., 2019). The algorithm was configured to generate only rules with the class (dropout) in the consequent. A minimum support of 0.15 was established to filter infrequent rules. The confidence was set to a minimum of 0.7, to consider only the rules in which the consequent is true for unless 70% of the instances for which the antecedent is true.

2.3 Sources and Datasets

Raw data were generated at the collaborating university. The R scripts and derived data that support the findings of this study are openly available in “Mendeley Data” at https://data.mendeley.com/datasets/pn8k5xp37c/1; the datasets and the R source code are shared to reproduce our work, a fact that does not happen in many experiments of this type (Gardner et al., 2019).

3 Results

Table 2 summarizes the results obtained for different models trained under different parameters, as resulting from the explorations to fine-tune the parameters described in the previous section. First, the max depth was tested by adjusting its value from 3 to 7, and the best result was obtained with a value of 5. Subsequently, the prior parameter was fine-tuned, the probabilities with which we worked were 0.5–0.5, 0.45–0.55 and 0.41–0.59, and the best results were obtained with 0.45–0.55. Finally, the size of the decision trees was modified through the parameter complexity-CP, and the value that achieved the best results was 0.1159.

In total, nine adjustments were made. Table 2 shows the metrics for the models with better results after this tuning process, with the corresponding algorithm parameters (for every case the values of min split, min bucket and max depth were 20, 7 and 5, respectively, so these are not shown in the table).

Model 4 in Table 2 is the final model with the best performance. The predictor is able to detect as dropout more than 80 per cent of dropout students in the test data, while the total accuracy is 0.76. When adjusting the model, our focus was to increase the TP rate for the dropout class, while keeping a moderate FP rate for that class. This was achieved as evidenced in Fig. 1, which shows the obtained ROC curve, with an AUC value of 0.78 for this model. The ROC curve is very helpful to evaluate models when working with highly imbalanced test sets due to their interpretability and validity in these data, a fact that is not our case, in our study it was used because it is adequate to assess how well an algorithm classifies the students relative to dropout (Coleman et al., 2019). Also, the sensitivity–specificity curve in Fig. 2 shows the tendency of our model towards the right angle in the upper right corner of the graphic, so TN rate keeps a moderate value.

In turn, Fig. 3 shows the tree decision model obtained. According to it, the two most relevant attributes that influence on the possibility of leaving university studies

Table 2 Results of the predictive models

Model	Partition 80–20						CP	Priors
		NO[a]	YES	PRC	TN/TP rate	ACC		
1	NO	23	6	0.61	0.79	0.62	0	–
	YES	15	11	0.65	0.42			
2	NO	20	9	0.77	0.69	0.73	0.0626	0.45, 0.55
	YES	6	20	0.69	0.77			
3	NO	23	6	0.62	0.79	0.64	0	0.45, 0.55
	YES	14	12	0.67	0.46			
4	NO	21	8	0.81	0.72	0.76	0.1159	0.45, 0.55
	YES	5	21	0.72	0.81			

[a] YES/NO values indicate whether the student drops out
PRC precision, *ACC* model accuracy

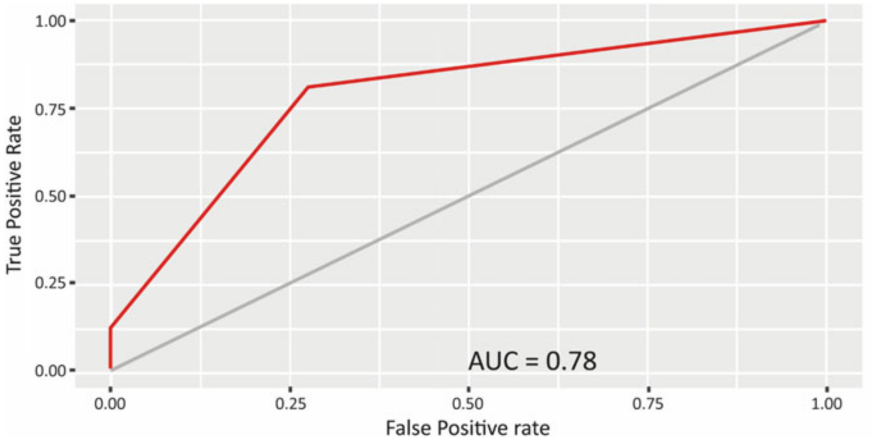

Fig. 1 ROC curve

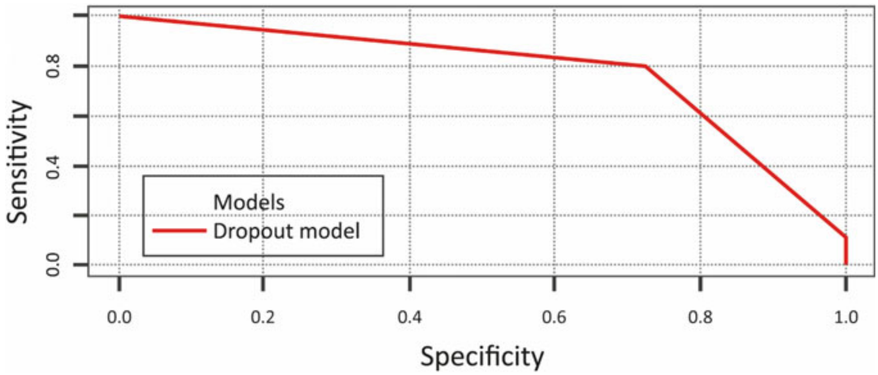

Fig. 2 Sensitivity versus specificity chart of best model

are city of residence and pre-grade STEM test scores. According to the model, most of students who do not live in the same city of the university will leave. For those who have the residence in the city in which the university has its premises, the school performance in STEM subjects will determine the possibility of abandoning.

For a deeper study about the potential influence of other variables, we analysed the association rules with support equal or higher than 0.15 and confidence equal or higher than 0.7. In Table 3, we list some of the most specific rules obtained, that is, those with more attributes in the antecedent.

Rules with better metrics correspond to the non-dropout students (Dropout = NO in the consequence). This is the reason why only rules related to non-dropout students are listed above.

As the decision tree model shows, this model also considers the city of residence as a relevant attribute, as this appears in many of the learned rules. Being single

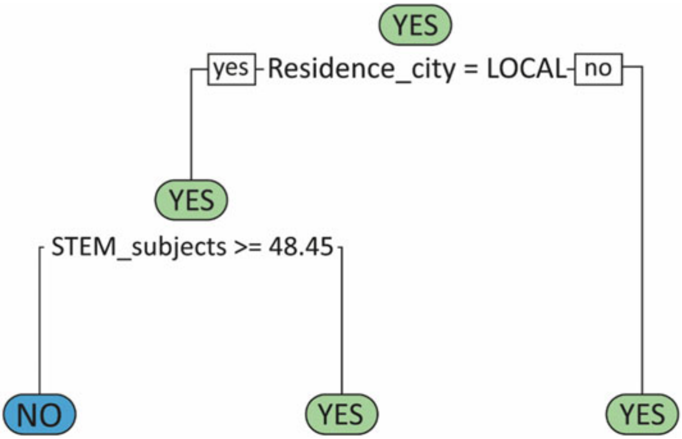

Fig. 3 Classifier tree model

Table 3 Most relevant and specific association rules

Rule	Support	Confidence
{**Residence_city =** Local, **Civil_status =** Single**, Mother_level =** Professional} ⇒ **{Dropout = NO}**	0.18	0.70
{**Residence_city =** Local, **Civil_status =** Single**, Desired_Program =** No Specified**, Mother_level =** Professional} ⇒ **{Dropout = NO}**	0.17	0.70
{**Residence_city =** Local, **Civil_status =** Single**, State =** Local,**Desired_Program =** No Specified**, Mother_level =** Professional} ⇒ **{Dropout = NO}**	0.17	0.70
{**Residence_city =** Local,**Civil_status =** Single**, State =** Local,**Province =** Local**, Mother_level =** Professional} ⇒ **{Dropout = NO}**	0.15	0.72

(rather than married or divorced) is another factor that facilitates continuing studies. The model also suggests that a higher level of studies from the mother may influence positively to students. Last, having the residence city located within the province of birth, being that city the same of the university is another characteristic present in some non-dropout students.

4 Discussion

As observed in the final model reported in Table 3, the prediction rate yields a 0.76 accuracy, although we are especially focused on adequately detecting the actual dropouts. Focusing on the TP rate, the model can identify more than 80% of students who will abandon their university studies.

4.1 Comparison with Similar Studies

These results can be compared with other studies: for example, from 509 records, Meedech et al. (2016) obtain 0.8 accuracy taking into account personal and educational background, as well as student's social behaviour and student's academic performance in the first semester. Chung and Lee (2019) consider behaviour of students during their first weeks of the course, obtaining a sensitivity of 0.85, while a specificity of 0.95, with 2050 dropout students out of a total of 165,715 students. In this sense, our model achieved moderate accuracy (0.76) but with data collected before starting studies, a fact that can help institutions to prevent dropout from the moment students enrol.

While the results for this model are lower, they are comparable, and it is important to remember that this prediction is based solely on data available during the enrolment period, while other studies leveraged data collected after the course had already started. Intuitively, using data of the academic course in progress should yield better predictions, because relevant information may already be available as the results of exams.

However, our model yields significant predictions at a much more useful time frame for offering support or alternatives to prospective students, detecting their risk factors before the first class.

Observing the model that was trained, our experiment highlights the city of residence and the previous academic performance in STEM subjects as the most influencing factors for university dropout in students of the computer science degree at the collaborating university. As other previous studies suggest, there are pre-grade factors, as demographic ones or school academic performance (Barbé et al., 2018; García-Ros et al., 2018; Hamoud et al., 2018; Iam-On & Boongoen, 2017), which can help when predicting university dropout. In fact, our work supports this. Differently from other studies that only considered a few demographic data, we have included a wider variety of factors from school to family background. This result is in accordance with the findings of Iam-On and Boongoen (2017) regarding the relation of school academic background and dropout risk. On the other hand, although Barbé et al. (2018) do not find GPA to be related to attrition in their sample, they clarify that academic requirements for admission were high. Regarding the city of residence, Cantón-Roda et al. (2019) find that this also drives the decision to enrol in a graduate program. Finally, it is interesting to highlight that our study suggests that family background as the level of studies of the mother may influence positively to students, which is in accordance with the findings of Arias Ortiz and Dehon (2013).

Dharmawan et al. (2018) detected dropout using non-academic data from university students in Indonesia. The information was collected through surveys and the Edward Personal Preferences Schedules (EPPS) instrument. The modelling was carried out with decision trees, SVM and K-NN. With the first technique, the same that we used, they reached a precision of 0.66, while we reached 0.76. Besides, as factors that influence the graduation of the students, they found the number of family members, interest in subsequent studies and relationship with lectures. The first two, as non-academic data, coincide with our study, and the third is presented when the student is already studying. In this sense, our model is interesting because it predicts dropout using data collected in the admission stage, that is, it anticipates possible university failure before students assume the university life.

In the scope of our work, dropout prediction models have been built with decision trees. Timaran Pereira and Caicedo Zambrano (2017) discovered socio-economic and academic profiles of university dropouts. The study worked with a dataset of 6870 students and the C4.5 algorithm. The work showed the low level of undergraduate tests as one of the relevant factors that influence dropout, in the same way, the residence city; this fact matches our model. Our study complements the above, in the sense of building a predictive model with data from aspirants and not from students enrolled.

Dropout has been also predicted with inferential statistical techniques and data analysis. Hori (2018) used sparse logistic regression as a method to identify factors that contribute to university dropouts. A dataset of 410 students from the faculty of Business Administration at the University of Asia was used; specifically, the study analysed what courses influence dropout. In another study, they analyse students' characteristics with big data tools and how crossing them influence dropout (Asha et al., 2020). Our study, compared with the previous described, goes beyond the statistical analysis because it applies a supervised machine learning technique and builds a predictive model with data provided by aspirants in the admission stage.

4.2 Lessons Learned

A deeper analysis facilitated by the association rules suggests some relation between some demographic factors and study persistence. Both the tree model and the association rules point to living at the same city of the university as one factor influencing in being successful at university. In fact, according to the study of Viloria and Pineda Lezama (2019), class attendance (facilitated by living at the same city) influences positively to college adaptation, which in turn influences college satisfaction. The single civil status and the professional level of studies of the mother are other additional attributes retrieved by the rules model.

These findings may give some light to educational stakeholders to take some measures to prevent dropout, giving the appropriate services to facilitate studying for those who do not live near the university (for non-distance universities) or for those who have stronger family responsibilities. Digital transformation in universities provides more virtual spaces that contribute to alleviate the barriers of space and time but, although the number of users of the virtual spaces is growing, the Internet infrastructure continues underdeveloped in some countries in Latin America and Caribbean area (Katz & Callorda, 2018; Revinova & Chavarry Galvez, 2020). Moreover, socio-economic differences exist, and studying online is a challenge for students from poor households (Basto-Aguirre et al., 2020).

According to the study of Mendoza (2020), low-income and rural students have less access to higher education, who are absorbed by less prestigious institutions. Therefore, there are clearly problems of access and equity. Besides, the study of Mendoza (2020) finds that lower-income students show an overall insufficient secondary education, which lead to poor academic outcomes. For example, according to Basto-Aguirre et al. (2020), only 20% of 15-year-old students studying in socio-economic disadvantaged schools in Latin America can access to an effective online learning space, compared to 50% of those attending advantaged schools. Besides, they state that access is not enough but also support is needed for less advantaged students and families to learn digital skills.

Moreover, there are other studies finding that psychological factors and general learning competencies influence having success at university, e.g. sense of coherence and self-regulated learning, as reported by Salamonson et al. (2016); sense of coherence and self-efficacy as reported by Van Westhuizen et al. (2011); lack of self-confidence, as stated by Barbé et al. (2018). Therefore, these are competences that must be promoted since early educational stages to promote persistence in studying at higher educational levels, as university. In the same way, enquiring on demographic aspects may serve decision-makers to define policies that promote fair and equal education opportunities.

The adoption of learning analytics services is incipient in higher education institutions in Latino America. From quantitative and qualitative data obtained from interviews with managers, teachers and students in Latin America, Hilliger et al. (2020) studied the needs for learning analytics adoption in Latin America universities. They found that managers need quality information from staff to evaluate support interventions. These authors believe that the adoption of these technologies will allow beneficial effects in learning outcomes. As the present study shows, learning analytics technologies allows deeper insights into the existing challenges in Latin America such as high dropout rates.

4.3 Limitations and Future Work

It must also be noted that our study presents some limitations. As discussed by Henderikx et al. (2017), academic failure and voluntary withdrawal should be distinguished in dropouts. In other case, we could get erroneous conclusions. The individual intention and perspectives, as well as the contextual situation at the moment of leaving studies, may determine the individual sense of failure. A limitation in our study is that both types of dropouts were not distinguished. As future work, it would be interesting to study the characteristics of the students with risk of academic failure, apart from the characteristics and motivations of the students who voluntarily quit studying. The difficulty will be to retrieve the explicit reason for leaving from the students, since the universities are not usually notified of their dropout but they simply do not renew their tuition.

Most generated association rules in this study, whose objective was to facilitate a deeper analysis, do not comply with the minimum stablished metrics of support and confidence. Moreover, no relevant rules were obtained to characterize dropout students and only a few were obtained for successful students, which allowed to describe a proportion of these ones. In the future, we will experiment with other non-supervised techniques. Given that research work on clustering and examination failure is scarce (Dutt et al., 2017), in the future we will consider clustering methods as well as other learning analytics techniques, e.g. latent class analysis, which have not been widely used in educative contexts (Xu et al., 2013).

Finally, as future work we also intend to collect more data to increase the size of the dataset, publicly available, and to extend the research to students in other grades.

5 Conclusions

This study has analysed how demographic aspects and pre-grade academic background can help to predict university dropout during the university admission period. Using available data from a specific university, our approach has proven to be a viable method to predict dropouts at the admission stage.

The dropout prediction model built with a decision tree and association rules corroborated some characteristics that influence college dropout and evidenced others that benefit the continuation of university studies. The city of residence and the previous academic performance in STEM subjects are the most influencing factors for university dropout in the students of the computer science degree of the university participating in this experiment. Besides, the obtained results suggest that family background aspects as the level of the studies of the mother may contribute to the success of students.

Dropout prediction models provide with some light to the educational stakeholders to prevent dropout. This is especially relevant in STEM studies in Latin America countries, in which socio-economic differences are a key problem that must be targeted during the needed process of digital transformation in education.

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A Personalized Brand Proposal Based on User's Satisfaction and Curriculum Supported by an Intelligent Job Recommender System

Nelly Rigaud Téllez and Patricia Rayón Villela

Abstract One of the main challenges' universities are confronted is the personalization of education services to improve quality mechanisms and strategies for supporting and assisting students when entering the workforce. Although many universities try to narrow the gap between academic life and job market, it is a highly challenging task to identify the right job for the right graduate. Market strives to find the most talented people and universities attempt to enrich students' personal brands, but these do not always align. Pitfalls are found in obtaining proper information that harmonize employment offers, course content and graduate's profile. This research places a transversal analysis of job mismatch in Latin American (LATAM) countries, builds a personalized brand based on satisfaction and course content and offers descriptions for an intelligent job recommender system. Proposal considers that providing a targeted job match implies by picking quantitatively relevant technical knowledge and transversal competencies of individual graduates and matching them to knowledge, skills and attitudes of employment offers and course content, in an efficient manner. Competencies from employment offers obtained with text mining are related to those from a current curriculum to help graduates bring about a personal brand for an appropriate job. Contribution of this research is the construction of a framework to construct match patterns that benefits graduates to meet professional success and to achieve personalization and optimization of the universities' offered services that represents an incremental improvement.

Keywords Intelligent job recommender system · Fresh graduates · LATAM universities · Competencies · Personal brand

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1 Introduction

Based on artificial intelligence, new opportunities emerge, as happens in diverse high-tech applications that has put forward new technological transformations and demands for the construction of information employment services and modes of employment for Latin American fresh graduates.

Universities set a wide range of educational settings, often beyond the course sequences historically offered to students, for instance, summer schools, independent research projects, online classes, internships, student exchange programs or dual-enrollment experiences. The importance of providing students with broader knowledge and skills is to allow them to access, thrive and keep themselves in labor markets (Wood & Breyer, 2017). These efforts are intended to teach students and graduates how to do a job, how to get a job, and, moreover, how to initiate a job.

Despite the fact that graduates of higher education in LATAM increased an average of 40%, a recurring theme in vocational education focuses on a skills mismatch challenge (ILO), where fresh graduates in emerging middle-income economies tend to suffer much more of their qualifications: A university graduate who has got diplomas and certificates lacks the required skills to find better-matched jobs (ILO).

According to the International Labor Organization (ILO), imbalances between skills and qualifications available on the labor market and those required in jobs are founded in different causes; one of them is deficiencies to manage information flow, where information asymmetries remain between jobseekers, offering jobs and the institutions providing education (ECLAC-ILO, 2019).

The lag of education and training systems (skill supply) behind the requirements of firms (skill demand) creates a 25.4% mismatch in Latin America and the Caribbean (ILO). This represents difficulties in fully understanding the quality of graduates and their employment expectations (Kaplan, 2009).

A study carried out by the National Association of Universities and Institutions of Higher Education (Anuies, 2013) reveals an effort in finding employment affects 40% of university graduates. This represents job hunting and recruitment complications. Additionally, existing literature presents evidence of the links between higher educations, employment and economic performance, where Peruvian, Brazilian and Colombian Ministries of Labor stated that 72% of graduates of HEI must pass further study at their workplaces, and employers pay for additional training for a quarter of their employees (Moreno-Brid & Ruíz-Naples, 2009).

On the side of employers, in Latin America, the recruitment and selection process are critical human resources functions. Public and private organizations hire potential graduates through traditional means, for example, newspaper advertisements. Staff analyze résumés by matching competencies and job requirements. Interviews and tests are regular activities, trying to ensure best-fit staffing with low biases and subjectivity.

By this employment method, an employer cannot fully grasp technical, professional and information technologies (IT) competencies, and the development status of university graduates, even if they could be overqualified.

Consequences are well known; when skills and jobs are mismatched, both employers and workers may have challenges in productivity, earnings and job satisfaction. It also may increase staff turnover and hinder investment or deployment of new technologies, products or services (ILO,).

To develop a career guidance and labor market information system to aid fresh graduates and at the same time to reduce job search costs and improve job matching the development of artificial intelligence can be employed to the process of talent acquisition (Zawacki-Richter et al., 2019).

This research is a proposal where artificial intelligence is recognized as one of the central enablers of digital transformation, in this case, on identifying competencies from a bachelor curriculum, based on his/her global satisfaction, technical knowledge and transversal competencies, by integrating a personalized brand construction. To attain best qualified graduates for a particular position, recommender systems and artificial intelligence (bot) are a possibility to improve speed, accuracy, objectivity and cost-effectiveness in recruitment and selection of university graduates (Zawacki-Richter et al., 2019).

The objective is to build a personalized brand based on current curricula course content and description of offers for an intelligent job recommender system, where Higher Education Institutions (HEIs), graduates and organizations could benefit from artificial intelligence (AI)-based systems for human resources (HR) selection, by matching fresh graduates to professional competencies and capabilities required by the public and private sector. Specifically, this chapter provides, in Sect. 2, an overview of related works regarding the concept of competence, as an amalgam of knowledge, skills and attitudes appropriate to a specific context and the actual challenge faced by LATAM universities to make them visible and their alignment with the business world. Additionally, in the following paragraphs, it is intended to clarify and define notions of personal branding, recommender systems and job recommender systems, and update readers with recent advances in the state-of-the-art technologies which aims to support our proposal.

Section 3 describes an architecture designed to construct a personal brand to match job offers, based on competencies and preferences of graduates by means of artificial intelligence, to meet professional success. Finally, the implications for LATAM universities and principal conclusions reached to the date are described in the last section.

2 Related Works

The transformation process seeks to leverage digital transformation on several ideas, and creating a job recommender system requires a certain amount of data. LATAM universities produce large volume of data about students' performance. The challenge is to find adequate use of data and its transformation into knowledge, in this case, to extract competencies, construct a personal brand by means of advances in text mining and a variety of intelligent techniques and methods.

2.1 Competencies, Course Content and Learning

The main objective of universities is to achieve the integral development of graduates and the competencies that a student has learned throughout his/her studies, where competency is the capacity of acting with determined performance and adequately fulfills tasks and activities in the domain of a particular knowledge. Universities should be able to identify the requirements of the labor field and stay up to date according to the profiles required by employers.

This means that HEI can play a leading role as a driver of socioeconomic deployment, so they must develop curricula not only for the development of curriculum competencies to enhance a cultural dimension, knowledge, skills and attitudes (Ferreyra et al.). Curricula must also be adapted to the demands of the public and private sectors. These ideas are based on the belief of allowing new professionals to increase production and generate innovative products/services for LATAM countries (Spinks et al., 2006).

According to the Union of Latin American and Caribbean Universities (UDUAL), multiple types of HEI consider the importance of quality assurance of their study programs to suit the real needs of the market and to promote mobility and employment opportunities (Pennington & Escalante Semerena, 2019).

The education system has transformed the way learning is conceived, and the competency-based approach arises because of labor and social demands on education systems, requiring the collaboration between the business world and the education system that allows for the training of professionals with skills and competencies that can be applied in various contexts together with attitudes and values. The competency-based model from Vázquez (2005) allows for a person to achieve an education where learning is a means for the development of the person as a social and individual being. Integral formation can be achieved by integrating skills, attitudes and values. The objective of the study programs is to build curriculum based on the needs that society demands (Vázquez, 2005).

The difference in the description of skills and competencies in curriculum, the quality of higher education as well as other social and professional factors can influence the different job offers (prospect jobs), even if two students have completed the same degree at different universities (Statistics, 2011).

At this point, the International Institute of Higher Education in Latin America and the Caribbean UNESCO-IESALC (IESALC, 2018) recognized the need for more transparent processes in terms of quality culture and standardization. One challenge, as indicated by the National Council for the Standardization and Certification of Competency (CONOCER, 2018), is the need to reach agreement and unification on expected educational outcomes.

Today, LATAM universities are directing their efforts to obtain recognition of their programs through accreditations from organizations, for example, Accreditation Council for Engineering Education CACEI (2017), where academics generate evidence from curriculum activities and a range of sources to show inspectors that competencies are enacted.

Accreditation systems point in the direction to attain transparent accountability of competencies, by making public the degree of quality of a university or an academic program (Ferreyra et al., 2017a, 2017b). For instance, standard datasets often measure outcomes of employability of graduates, applicability of research and innovation results, but other quality measures of student's ability, effort and academic readiness are generally not available, even if they are through end-of-university competence examinations (IESALC, 2018).

As noted, accountability measures are not easy to obtain when it is about the outcome of assessment level of competence. Furthermore, HEI must provide means for the identification of measurable competencies linked to the content of academic subjects and to what extent identified competencies satisfy market needs (CONOCER, 2018; Pennington & Escalante Semerena, 2019).

In the arena of assessment, there has been significant research on competencies and their evaluation (Robbins, 1996; Puchol, 2005; Rozencweig-Lemaitre, 2005; Shiemann & Metrus Group, 2007; Noe et al., 2009; Lopez et al., 2020), where each author based on a recognized framework proposes models, methodologies, schemes and instruments.

Authors concede that the assessment of competencies should consist of at least a discovery of competence or the identification of required competencies, means of assessing acquired competencies, competence analysis to match acquired and required competencies, and competence development as a basis to provide recommendations for improving complexity of mental processing.

Considering the main problem of skill mismatch in universities from LATAM and real market needs, this research orients to recruitment and selection in two aspects: competence discovery and competence matching. Based on López (2020) and (Bohloli et al., 2016), a competence level is determined through a performance verb and what follows the verb, where learning objectives and outcomes represent a result of learning.

Most of the competencies described in the curriculum are obtained from Bloom's well-known taxonomy, which concentrates a list of verbs according to different cognitive levels. This represents an important stage in the representation of competencies that will be used throughout this chapter (Sánchez et al., 2016). Also, transversal skills gained from the perception of employers in different studies tend to converge on a list of common competencies (Hurtado et al., 2019).

Additionally, there are three actions to facilitate employability: designing an appropriate training profile, considering the practical dimension of the curriculum and developing actions to facilitate job insertion (Ferrer & Cano García, 2014). It is important to note that according to employers, a university degree is a guarantee of the candidate's theoretical training in each field of knowledge. This is confirmed by a survey where a deficit in theoretical training is not detected (Sánchez et al., 2016).

Extraction of competencies has been studied in the Cuban University (Hurtado et al., 2019), where the result of a certificate has a list of courses that do not clearly indicate the competencies and the degree of these, so it is necessary to have a tool that allows the description and extraction of them.

Table 1 Configuration of curricula courses and associated competencies

	C_1	C_2	C_3	C_4	.	C_n	TC_1	TC_2	TC_3	TC_4	…	TC_n
Course 1												
Course 2		X				X		X				
…										X		
Course n		X										

Source Prepared by the authors

According to Malacara (2020), "Due to the lack of opportunities and the need for employment, many young Mexicans become entrepreneurs and work in positions that are far from the career they studied and their initial job projection," another important fact to highlight is that 50% of Mexican professionals do not practice their own work, and 52% of companies claim to face difficulties in filling their vacancies, according to the 2020 Talent Shortage study of the human capital firm Manpower. In the case of Peru, Piscoya (2019) identifies a serious problem in the labor insertion of Peruvian university graduates. Three out of ten graduates would be improperly employed, carrying out activities in non-professional occupations that could be carried out by workers with a lower educational level. On the other hand, in Colombia, according to Labor Research (2019), many young Colombians work in positions other than their professional careers and with the projection they had contemplated. When looking for jobs, they prefer to share their resumes with contacts who can reference them, which can lead to the search for a job that does not necessarily match the skills of the applicant.

A graduate, who has successfully completed his/her study, has achieved final competencies. In addition, crosscutting or transversal competencies are of great importance to employers and, therefore, must be considered. Verifiable and evaluable competencies acquired throughout different courses require one or more verbs. Table 1 summarizes bachelor's competencies C_i and transversal competencies TC_i obtained in each of the curriculum courses.

Table 1 provides a schema to identify final competencies. This makes it possible to obtain the degree a subject contributes toward the fulfillment of a competence. Additionally, The extent to which graduates attain a competence and to what extent that competence satisfies a job offer from public and private sectors.

For instance, actual trends demand that organizations become increasingly agile and embrace disruption. The world including LATAM is focusing on interconnectivity, big data, cloud computing, machine learning and artificial intelligence. Future competencies from courses will be critical, as well as crosscutting competencies, such as complex problem solving, critical thinking and creativity that have already become a core area of focus.

2.2 *Personal Brand*

Given the great loss of jobs due to actual times because of coronavirus, some recommendation to select a good job is the construction of the personal brand, as indicated by Rodriguez (2020).

Personal branding is a topic that is gaining strength in Latin America. Estrada (2019) presented a Latin American collaborative, educational, dissemination and positioning project, related to the topic of personal branding, whose objective is to promote personal branding in Latin America. Also, to improve the visibility and international positioning of Latin American talent linked to personal branding, as a base to support digital transformation through artificial intelligence (Banco Interamericano de Desarrollo, 2020).

Personalized brand construction is one of the most relevant tools to open professional and personal opportunities from a high level. Personal branding is associated with raising oneself, by offering qualities and competencies across boundaries of industries and organizations.

The core of personal branding refers in multiple ways as positioning, promoting, developing and marketing based on a unique combination of individual characteristics, to meet the changing needs of employers and customers, thereby helping potential work outputs (Shafiee et al., 2020). Thus, for career seekers, personal brand is an opportunity to offer their skills and competencies globally to attain career success in actual employment systems and project-based work structures.

Research points to three main features when developing a personal brand (Gorbatov et al., 2018).

(1) A strategic perspective, which relies on the idea that managerial activities are coordinated to promote oneself in the job environment to a target-specific audience.
(2) A differentiated way to achieve career benefits. To that end, the individual is required to identify his/her academic competencies conveying valued and unique individual characteristics, and how they fit into professional settings. After all, talents of fresh graduates, and more specifically, competencies they possess, can drive the success of an organization.
(3) Personal brand based on technologies. Advances in technologies bring about the ease of communication across numerous social media platforms as a primary vehicle to convey imagery to a target audience. Job seekers can estimate effectiveness of personal branding activities, to apply any adaptation and correction to improve their possibilities of good employment.

According to Gorbatov et al. (2018), personal branding is a strategic process based on a unique combination of individual attributes, which signal a certain promise to the target audience through a differentiated narrative and imagery.

Additionally, literature review represents a work in progress, when it is about fresh graduates. Authors dispose explanations, examples, case studies and models when graduates formulate their personal brands (Gorbatov et al., 2018). In HEI, graduates are supported to use self-marketing as a career management tool, but tend to be restricted in counseling programs, to elaborate a curriculum (Naidoo & Hollebeek, 2016).

To this respect, creating a personal branding based on technology helps graduates to easily understand requirements from the job market and better position themselves for job offers, therefore improvements for their recruitment and selection (Ilies, 2018). Also, fresh graduates have achieved a series of competencies; however, they still need to learn about their personal development (broaden their knowledge about competencies and appraise the talents they need to reinforce) to create a better image and reputation in the labor markets. Moreover, graduates can better understand the meaning of branding, how to use it and its potential outcomes.

In this setting, personal branding for fresh graduates should be a subject to ongoing adjustment and change. Based on technologies, their personal brands require maintenance and decisions on how to best position their skills, knowledge and values within the context of their future professional orientations.

Creating a personal brand requires a process, as shown in Fig. 1.

In Fig. 1, improve self-knowledge refers to define competencies through a dynamic approach to study how individuals want to be perceived by their target audience. Develop a brand vision has to do with the acquisition of reputation, so it is important to project the desired self and perceived identity comprised of core identity (education, skills, personality, values, experience, etc.), extended identity (abilities, attitudes, cultural aspects, etc.) and value proposition (functional, emotional, self-expressive and relationship benefits).

When establishing a strategic brand, the aim is to define the brand core, by closing the gap between the desired identity, image and reputation in relation to those competencies and attributes that could differentiate and favor job offers in professional and social environments. A graduate establishes his/her strengths and abilities that could lead to a successful professional activity.

Fig. 1 Creation of a personal brand. *Source* Prepared by the authors

Also, in Fig. 1, establish a communication visibility refers to combine online channels to communicate in a consistent and coherent way unique characteristics to target audiences in a broad public and private sector.

As noted, building a personal brand denotes thinking in quality, not quantity, and the idea is not to be known by everyone, but by those sectors and individuals who might consider valuable graduate competencies. Also, personal branding requires technological means to favor communication.

2.3 Recommender Systems

As highlighted by Urquidi and Ortega (2020), artificial intelligence represents a great opportunity to increase the efficiency and effectiveness of Public Employment Services, to carry out appropriate recommendations for job seekers, selecting the better job openings, and help employers identify the best fit for their hiring needs. Although Paraguay has made use of AI, there is still a long way to go, and several countries have started to consider AI in these services. Peru, Colombia and Mexico are perhaps the countries that have advanced the most so far, but they contrast with the situation of European nations that have these AI-based systems with proven results and foresee that in the future there may be a wide range of applications that can be implemented by labor intermediation services, at a public and private level (Banco Interamericano de Desarrollo, 2020).

In traditional recommender systems, three different methods are used (Mohanty et al., 2020): (a) content-based, (b) collaborative filtering and (c) knowledge-based selection systems, as shown in Fig. 2.

These methods are described below.

2.3.1 Collaborative Filtering Methods

Collaborative filtering uses information about the rating that users give to the product of interest. If two users are similar, the algorithm will try to identify this similarity between users, so in cases where only one user has given a rating to the product or item of interest, it is highly likely that the same rating will be obtained from the other user who has not yet given it a rating. Based on this, the system will be able to predict these values. The use of correlation between users and between items (products) is used in collaborative filtering to be able to make this prediction.

In such a recommender system, rows will represent users and columns to selection items, as shown in Fig. 3.

In such recommendation systems, arrays are sparse and the goal is to predict those empty elements, based on similar content previously selected by the user. Some models use training models that then allow to predict or assign a rating to items that do not yet have an assessment.

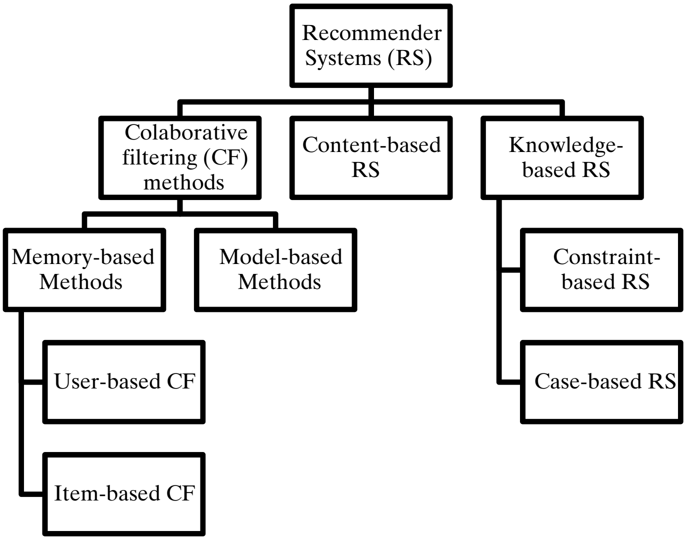


Fig. 2 Methods for recommender systems. *Source* Prepared by the authors

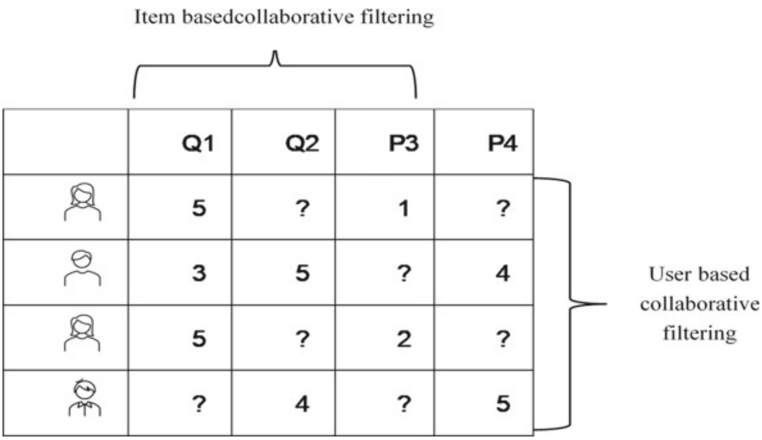


Fig. 3 Collaborative filtering. *Source* Prepared by the authors

There are mainly two methods of collaborative filtering, memory-based and model-based.

In memory-based methods also known as *neighborhood-based collaborative filtering algorithms*, the qualification of user-item combinations is predicted based on their neighborhood. This neighborhood can be defined in two ways:

- **User-based collaborative filtering**. The ratings provided by similar users are used to make the recommendations between them. The use of similarity functions is used in the rating matrix to identify these similar users; in this way, for instance, if two users have rated a movie in a similar way, these ratings can be used to predict the other one. The most similar *k* users are generally used to make predictions about some products.

- **Item-based collaborative filtering**. To make predictions from a user, it is necessary to determine a set of similar products; in this case, the similarity is carried out per column to find these similar products.

The advantage of these methods is that they are easy to implement. Collaborative systems use a correlation between rating patterns and users to make recommendations. These methods do not use element attributes to calculate predictions.

A critical step in this recommender system is the calculation of the similarity between items, where the items that users have evaluated to determine the similarity between them are selected. One of the most used measures is the cosine-based similarity, where two vectors in an m-dimensional space are calculated by the cosine angle between those two vectors; also, correlation-based similarity that uses the calculation of the R correlation of Pearson and adjusted cosine similarity are used (Sarwar, 2001).

For item-based filtering, the similarities between items (columns) are computed. Before the computation is done, each row is centered to a mean of zero, and then the adjusted cosine similarity is used. Also, the Pearson correlation can be used, but the cosine provides better results (Sarwar, 2001). The comparison of seven similarity measures, including Pearson correlation, cosine vector, frequency-weighted Pearson correlation, was presented by Hassanieh (2018). They conclude that weighted Pearson correlation had the best accuracy of predictions when the dataset was sparse, and when the dataset was dense, Spearman rank correlation similarity had the highest accuracy.

Once the similarity between products has been calculated, it is necessary to carry out the prediction, which can be carried out by weighted sum or regression techniques.

Model-based methods: Such methods use machine learning and data mining methods. Examples of this type use decision trees, Bayes rule, rule-based methods, Bayesian methods and more.

2.3.2 Content-Based Selection System

Unlike collaborative recommendation systems where pattern correlation is used, in content-based recommendation systems, elements are described by their attributes (Falk, 2019).

Content-based systems rely primarily on two data sources:

1. Item profile construction. The description of products or elements, using feature extraction techniques.
2. User profile construction. The second data source is the user's profile, which will contain the user's preferences, as well as having user feedback explicitly

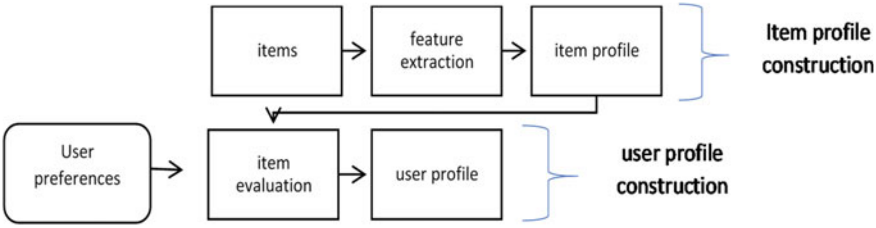


Fig. 4 User and item profile construction stages. *Source* Prepared by the authors

or implicitly. Explicit feedback corresponds to ratings that are collected in a similar way to collaborative systems.

In this type of system, one must have a representation of the user's preferences. User can specify their own profile in terms of keywords and the ratings of other users are not used in this type of recommendation system.

A general approach for the principal stages in this type of recommender system is shown in Fig. 4. It is important to keep in mind that the user profile can change during the recommender system and also is recommended to avoid that the systems provide recommendations that user has consumed before.

Item profile construction. Because the item's description is an unprocessed text, most of the common feature preprocessing techniques related to natural language processing tools are used, where the description of the items is analyzed to extract the best representation of them.

The most common steps in feature preprocessing and extraction are (Sarkar, 2019; Anuj, 2020):

Sentence segmentation. Breaking up a given text or paragraph into sentences.

Word tokenization. Tokenize a sentence into words, considering the presence of punctuation marks or white spaces.

Stop word removal. There are usually common words that have little significance and are called stop words. There is no universal *stop words*, but it depends on the language and sometimes own domain-specific *stop words* are needed.

Stemming and lemmatization. Stemming is a crude process that can result in chopping off the ends of words, reduce each word to its origin or stem in a family of words called stemming. It helps to reduce the number of words to analyze. *Lemmatizers* match every word to its lemma, the form in a dictionary.

In a content-based recommendation system, feature preprocessing and extraction must be performed to the items (Charu, 2016), and these are represented by a set of features (Lops et al., 2011). The selection and weighting of these features can be carried out by using supervised tools such as: Gini index, entropy and χ^2-statistic.

Most content-based selection systems use the vector space model (VSM) with basic TF-IDF weighting. VSM is a spatial representation of text documents. Each document is represented by a vector in an n-dimensional space, and each dimension corresponds to a term from the overall vocabulary of a given document collection. The term in recommender systems is represented by attributes or keywords.

Let set D D's "d_1, d_2, d_3, … d_n" denote a set of documents or corpus, and T "t_1, t_2, … t_n" be the dictionary, the set of words in the corpus T. Then, the term frequency-inverse document frequency (TF-IDF), where $f_{k,j}$ is the frequency of the term t_z tk in document d_j, is

$$\mathrm{TF}\left(t_k, d_j\right) = \frac{f_{k,j}}{\max_z f_{z,i}}$$

where the maximum is computed over the frequencies $f_{z,j}$ of all terms t_z that occurs in document d_j.

$$\mathrm{TF} - \mathrm{IDF}\left(t_k, d_j\right) = \mathrm{TF}\left(t_k, d_j\right) \cdot \log \frac{N}{n_k}$$

where

- N denotes the number of documents in the corpus.
- n_k denotes the number of documents or items in the collection in which the term t_k occurs at least once.

For the weights to fall in the [0,1] interval and for the documents to be represented by vectors of equal length, weights obtained are usually normalized using cosine normalization:

$$\mathrm{sim}\left(d_i, d_j\right) = \frac{\sum_k w_{ki} \cdot w_{kj}}{\sqrt{\sum_k w_{ki}^2} \cdot \sqrt{\sum_k w_{kj}^2}.}$$

One of the most used similarity measures is the cosine similarity function, where each item is represented by a standardized or weighted frequency using TF-IDF.

$$w_{k,j} = \frac{\mathrm{TF} - \mathrm{IDF}\left(t_k, d_j\right)}{\sqrt{\sum_{S=1}^{|T|} \mathrm{TF} - \mathrm{IDF}\left(t_s - d_j\right)^2}}$$

Another tool used is the Bayes classifier which will attempt to predict the probability that the user likes a particular item (Lops et al., 2011). Also rule-based classifiers use confidence measures. Regression-based models can be useful when the rating type is binary, interval-based or numeric. Some classifiers that can be used in this approach are the nearest neighbor classifiers.

User profile construction

One of the essential parts of this type of recommendation system is the learning of user profiles, when ratings are discrete values (like or dislike). The problem is like a text classification problem, but when they are numeric entities, not discrete, it is like regression modeling. Suppose there is a set of items that have been evaluated by the user, the training items will correspond to the description of the products, which are extracted in the preprocessing and attribute selection phases. In this training process, the ratings given by other users are not used, and this is an essential difference compared to collaborative filtering.

Content-based recommender systems rarely are used in isolation, they are combined with other types of recommender systems, and this approach is known as hybrid recommender systems.

It should be noted that other users' ratings generally play no role in a content-based recommendation algorithm. Also, when an article is new, it is not possible to obtain other users' score for that article. Content-based methods allow recommendations in such configurations because they can extract attributes from the new item and use them to make predictions.

On the other hand, the cold start problem for new users cannot be addressed with content-based selection systems. In addition, not using other users' ratings reduces the diversity and novelty of recommended items.

In a content-based recommendation system, you should build a user profile that will include his/her preferences, and the goal is to predict from their profile the recommendations that can be made to them. One of the advantages of this model is that the user profile can be built from the ratings that the user has given to some products.

The content-based recommendation analyzes descriptions of previously given items by the user and builds a model based on the characteristics of these user-qualified elements. The recommendation will be made using the attributes of the user's profile with the attributes of the element or object, and the result represents the level of interest of the user. The use of different strategies to be able to carry out this representation is used, such as the use of dictionaries and ontologies.

Mohanty et al. (2020) summarize the main ways in which the representation takes place and how the most common ones are presented.

A representation with the elements that satisfy each user is obtained, which will require obtaining the more similar elements, based on their description. This similarity can be done by cosine similarity, Euclidean distance or Pearson correlation. Therefore, the recommendation system will identify those more similar elements.

Different techniques have been used to learn the user's profile, such as probabilistic techniques using Bayes classifier, and supervised learning models, like decision trees and relevance feedback Rocchio algorithm.

Using probabilistic techniques, attributes are identified according to user preferences in c+ positive preferences and c− negative preferences. By using Bayes, it is possible to get the probability that a given product belongs to one of the categories.

Another supervised learning model that can be used to learn user profiles is a decision tree. The decision tree can be built based on the items the user has classified; for each user, a personal decision tree is constructed, based on the preferences of each one. One of the advantages to use this approach is that the interest of the user to those features can be inferred, and each user has its own model. A decision tree is built to learn the attribute preferences for each user.

These models can be used to predict the preferences for any unseen new items for a specific user. In many cases, recommended items can be user-obvious items, or they may be other items that the user has consumed before because they have similar attributes.

This approach shares some features with knowledge-based recommendation systems. The main difference is that knowledge-based systems perform an explicit specification with an interactive interface between the user and the recommendation system.

2.3.3 Knowledge-Based Recommender Systems

The cold start problem occurs when there is not enough user information to be able to make some recommendations. Collaborative systems are the most susceptible to this problem. In problems such as the purchase of a car, financial services are highly customized; therefore, there are not enough ratings. The product description becomes complex, so an interactive feedback is used.

A knowledge-based recommender system is appropriate when the customer wants to specify requirements, so interactivity is a crucial component. In content-based systems and collaborative systems, historical data is used, while knowledge-based systems are based on user-given specifications.

Knowledge-based recommendation systems can be classified into:

(i) Constraint-based recommender systems. In these systems, users specify requirements and domain-specific rules are used to match the user requirements.
(ii) Case-based recommender systems. It is an interactive process that does not finish until a desired result is achieved. The results are often used as new target cases with some interactive modifications by the user.

A feature of knowledge-based recommender systems relies on explicitly soliciting user requirements. The interaction between user and system can be conversational systems, search-based systems and navigation-based.

In content-based recommender system, initial user profile specification is very similar to knowledge-based recommendation systems. Such knowledge-based recommendation systems are known as case-based recommender systems. As the name implies, cases are used to guide the search along with similarity measures, while in constraint-based some criterion is included to guide the search. The goal is to modify the search criteria to obtain the recommendations.

Interaction with the recommendation system is an important feature to consider for such systems, and these can be conversational systems, search-based systems, where targeted questions are asked for more information, and navigation-based systems, where the users specify a few changes based on their preferences.

In case-based recommender systems, the user interactively specifies a sample of interest, and the nearest neighbors are retrieved as elements of interest to the user. There is less emphasis on historical data or ratings in knowledge-based systems.

2.4 Job Selection Systems

Traditional techniques such as Boolean search methods used in job portals are not capable of obtaining a good match between candidates and job ads, which results in organizations failing to attract valuable employees. Job recommender systems can help to improve this. For a recommendation system, one must have the candidate's resume and the job proposal, both represented by unstructured information, from which the necessary skills and requirements must be obtained to find a match between them.

A survey for existing job recommendation systems and techniques used for them is presented by Dhameliya and Desai (2019). The paper evaluates different approaches, major issues, methods and evaluation measures. Other techniques that integrate different methods, semantic matching, tree-based knowledge matching and query matching, are used by Musale (2016), and the proposed system lets the student search for a job using keyword-based search and get information from recruitment sites using Web crawling. A comparison of different methods for collaborative filtering is presented, approaches and evaluations are done by Mishra and Rathi (2019), and they mention that because of the cold start problem, the user's profile and job ads are not matched properly.

Different measures have been suggested for collaborative filtering, and the results shown by Hassanieh suggest that the weighted Pearson correlation had the best accuracy of predictions when the dataset was sparse. Some ontology-based approaches (Dada et al., 2018) are used in recommender systems, to enhance keyword searching and model user profiles (Rimitha et al., 2018).

As Mehta et al. (2020) conclude, using a hybrid recommender system is better to address the cold start problem, and a better result is obtained, which is one of the objectives of this article.

3 Proposed Architecture for a Job Recommender System

The transformation process seeks to leverage digital technologies to create or modify different types of experiences, thus meeting customer's changing needs, and this is where artificial intelligence comes into play. In the following section, a proposal is presented of how digital transformation coupled with artificial intelligence can deliver a possible solution to the match job problem for LATAM.

Proposed architecture aims to construct a personal brand to select an appropriate job, according to fresh graduates' competencies and preferences to meet professional success. To achieve this, acquired competencies from bachelor's curricula are used to construct a personal brand. To assure appropriate information for a personal brand, an adequate body of knowledge is used for the competence's extraction stage.

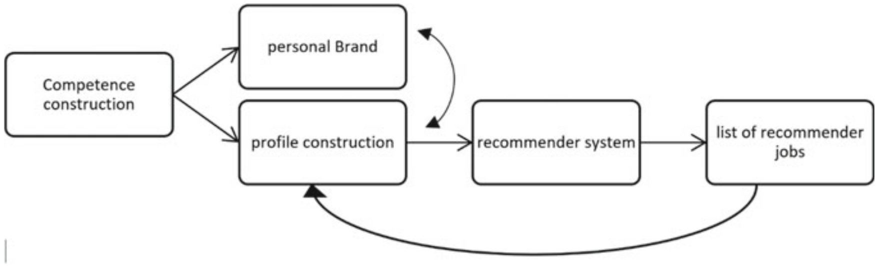


Fig. 5 Elements of the proposed architecture. *Source* Prepared by the authors

To avoid the cold start problem for the content-based recommended systems, a profile construction stage which uses the personal brand is proposed. A list of recommended jobs is obtained using a hybrid selection system.

The interaction with the recommender system in the architecture allows to improve the personal brand, using the keywords on the job offers that have not been considered, and helps to get an enriched list of job offers, as shown in Fig. 5.

The principal stages of the proposed architecture are competence and personal constructions, and an intelligent recommender system. These stages are described in the following sections.

3.1 Competency Construction

The essential elements included in the proposal are that there is a personal brand containing competencies presented by job offers and used to create a user profile for the recommender system, to be able to properly select appropriate job offers. Construction of competence stage is used to extract this list of competencies.

One of the main stages for the construction of competencies is to select the appropriate body of knowledge to extract the correct competencies and to achieve matching job offers with the competencies of fresh graduates. The body of knowledge used for this purpose will be made up of competence description, student outcomes, Bloom verbs, course names, job ads and future skills employers are looking for.

Many of the competencies that describe recent graduates are compound words, which in natural language processing can be identified as n-grams. Some examples of these n-grams are: "critical thinking," "problem solving," "data mining," etc. Therefore, a proper extraction of these elements is a key phase in the representation of the selection system.

One way to identify these n-grams is using the list of Bloom verbs that are used frequently on competence description; for example, the term "design software" is a bigram that has as a first word which is a Bloom verb. This term is also in the student outcomes for computer science students, in competency descriptions in a programming course and in job ads related to computer science. Bloom verbs are

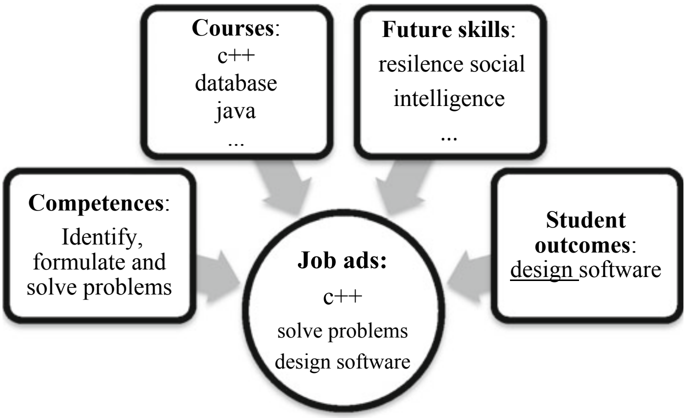


Fig. 6 Matching competencies and job ads. *Source* Prepared by the authors

a natural way to detect competencies, as mentioned. If a competence description or student outcome begins with a Bloom verb, this is selected as a candidate n-gram. Also, the list of courses is selected as a competence, like c++ , as shown in Fig. 6.

As described in the recommendation system stage, the extraction of keywords requires natural language processing steps that allow their identification. In the proposed methodology, normalization, punctuation removal, tokenization and stemming are used.

The methodology for n-gram construction is based on Bloom verbs, as mentioned, and a list of bigram and trigram candidates is obtained. Also, the bigram and trigram candidates are obtained from the course list like "computer networking." Using a threshold, these n-gram candidates are selected in the n-gram selection stage. Finally, the list of n-grams is sought in job offers, and then a final list is obtained. A stop word removal stage is obtained once the n-grams have been removed, and finally a list of competencies using word frequency terms is used. The methodology is shown in Fig. 7.

3.2 Personal Brand Construction

Personal brand encompasses a promise of the ongoing delivery of value. Fresh graduates require an initial step of improving self-knowledge to define themselves and promote their identity to better adapt and capitalize on business world opportunities. Thus, as mentioned in Sect. 2.2, a personal brand process starts with self-knowledge.

Personal brand allows an individual to analyze and define oneself using his/her unique personality, associations and traits, and based on the user's global satisfaction from course content and his/her final competencies define the real one. To do so, a pseudocode has been developed, as follows (Table 2).

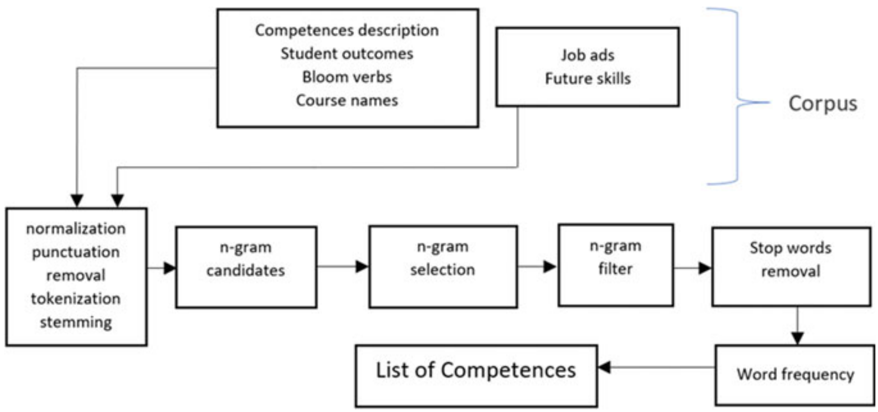


Fig. 7 Methodology for construct competencies. *Source* Prepared by the authors

From listed competencies, a graduate's academic record and final subjects' evaluations attempt to qualify each competency, defined by a bachelor's study plan.

N competencies are listed, and a score is assigned to each competency according to final evaluations from a graduate, where abilities, skills and attitudes are included.

A matrix is formed (Table 3) which includes as many lines as subjects, courses and certifications the graduate has studied and includes as many columns as competencies related to those studies.

Competencies listed are fulfilled by means of a scale. Once this process has concluded, the final evaluation of the subject for that competence is calculated.

The *n* competencies must be categorized, for instance, in critical thinking, complex problem solving, cognitive intelligence, just to mention a few of them, so that when they are integrated by subject, the graduate's aptitude can be determined, such as an initial personal brand.

The decision of whether a subject is part of the personal brand depends on a truth table (logical table) of competencies versus global satisfaction (subject content and activities), as shown in Table 4.

An outcome column is incorporated into this table.

The decision rule indicates if the graduate obtained an evaluation greater than 7.5. If the graduate obtained the same degree of satisfaction, then the competencies of that subject are maintained. Table 4 shows the possible combinations.

Personal branding result can be displayed graphically, as shown in Fig. 8.

3.3 *Recommender System*

The objective for a graduate is to have suitable job offers. The function of a job recommendation system is to relate user's main skills to job offers. To obtain this match, between user and job offers, a hybrid recommendation system is suggested in

Table 2 The Pseudo code for a Personal Brand's construction

```
Generate CompetentecesList (CL)
CompetencesCategories=Classification(CL)
CoursesList (Courses)
FOR Course Ci in CoursesList:
{
   Si= SatisfactionSurvey(Ci)
   ClasificationCourseCi=Clasif(GradeofCourseCi, Si)
       IF ClasificationCourseCi== YES
       FOR Competence Kj in CourseCi
           Competence(Kj)=GradeofCourseCi
}
FOR Competence Mi in CompetencesList CL:
   CompetencesSum(Mi)
FOR CompetencesCategory Ni in ComptencesCategories:
   CompetencesCategorySum(Ni)
FOR CompetencesCategorySum Qi in CompetencesCategories:
{
   IF (Qi) > threshold
       Include  Qi in PersonalBrand
}
Function Clasif(GradeofCourse(Ci,Si)
{
   If (Si == YES and Ci >= TresholdCalif)  or (Si==YES and Ci <=ThresholdCalif)
       return (Yes)
   else if (Si==NO and Ci >= ThresholdCalif)  or (Si==NO and Ci <= ThresholdClalif)
       return (NO)
}
```

Source Prepared by the authors

this work, which will have a content-based recommendation system and a knowledge-based recommendation system.

One of the main disadvantages of a content-based recommendation system is the cold start problem. Since there are no user preferences, it is very difficult to give a first recommendation to the user. To deal with this problem, it is suggested obtaining a first user profile by means of a personal brand, which can be enriched as part of the proposed architecture.

The search for jobs can be carried out by using some keywords to obtain a list of positions. However, in these systems there is no interaction with the user that allows the system to get more information, for instance, graduate's desires, necessity of skills, interests and abilities.

Table 3 Making competencies visible

Subject	Final evaluation	Global satisfaction	Category 1				Category 2			Category n		
			C1	C2	C3	C4	C4	C5	C6	C7	…	Cn
Algebra	6	9		6					6			
Economy	9	7	9				9					
Computer programming	8	5	8	8					8			
Systems engineering	7	7		7			7			7		
…	10	10								10		
Competency sum			**17**	**21**			**16**		**14**	**17**		
Category sum			**38**				**30**			**17**		

Source Prepared by the authors

Table 4 Logical table

Competence	Global satisfaction	Outcome
✓	✓	✓
✓	✗	✗
✗	✓	✓
✗	✗	✗

Source Prepared by the authors

Fig. 8 Personal brand. *Source* Prepared by the authors

For this reason, a knowledge-based recommendation system is used, as shown in Fig. 9, where the proposed architecture is described.

Content-based recommendation system has the disadvantage that sometimes same jobs, or very similar jobs, are obtained because they are the ones that are more like the profile. To enrich the personal brand and look for other attributes that were not included in the first instance, a set of randomly selected jobs will be selected to identify another attribute that the user likes and dislikes, as shown in Fig. 10.

An analogy in an optimization problem is like having fallen into a local minimum and moving a bit in this solution space to avoid always obtaining the same recommendations.

One of the essential characteristics of the proposed architecture is that it enables the cold start problem to be addressed, allowing the user to build the profile with

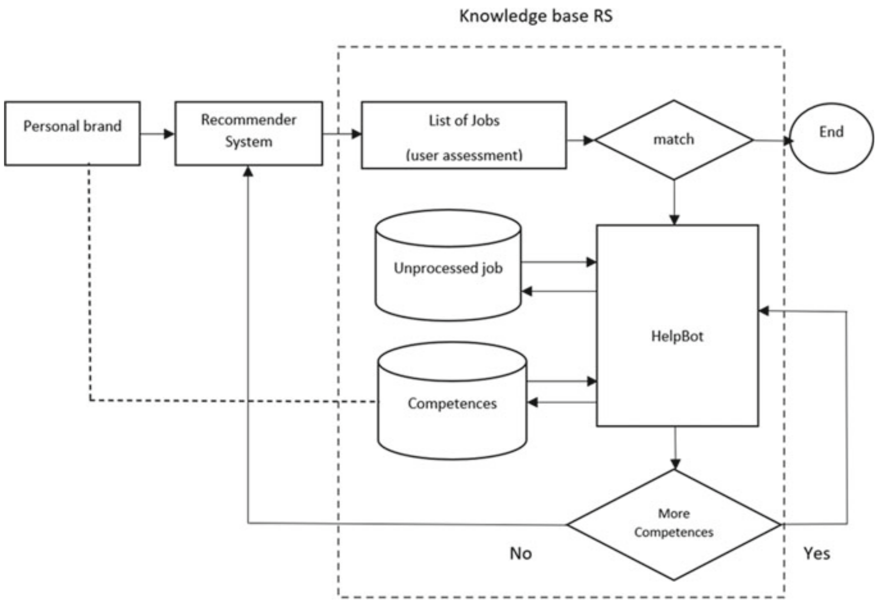
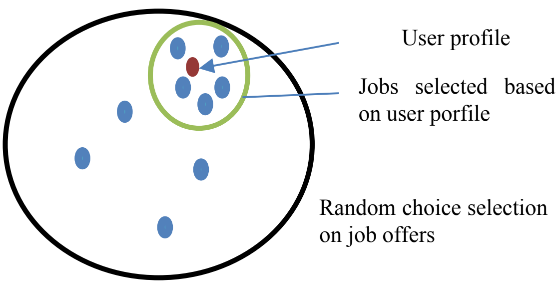


Fig. 9 Architecture of the recommender system. *Source* Prepared by the authors

Fig. 10 Selection process for job offers. *Source* Prepared by the authors



the data obtained from the personal brand. From this, a list of candidate jobs will be obtained. In case the offers are appropriate for the candidate, the system ends. If not, the interaction with the knowledge-based recommendation system is carried out, where the interactive part is carried out through a Helpbot. At this stage, the job offers are presented, and the keywords will be highlighted in it, indicating those that the student has selected and with which is identified. However, to obtain a list of jobs more related to their profile, it is required some additional information that has not yet been included. This is where the Helpbot is used.

Helpbot's function is to have a guided conversation to get more information about job offers. It helps to ask specific questions about what likes or dislikes; if there are new competencies that are not considered, then these are included in the competency database and in the user profile and personal brand.

Finally, when the user has included some different competencies, a new set of jobs are shown. The process ends when the list of jobs given satisfies the user.

4 Discussion and Conclusion

This chapter focuses on analyzing and proposing an intelligent job recommender system that uses content-based recommendation system and a knowledge-based recommendation system. In this case, to build a personalized brand that match to targeted jobs, this proposal considers current course content and job ads, to extract competencies from current curricula and global satisfaction.

The proposal is defined as an architecture to aid and support fresh graduates in securing the selection of an adequate job to meet professional success. The architecture ties acquired competencies from bachelor's curricula that are used to construct a personal brand. To ensure personal brand uses appropriate information, a suitable body of knowledge of revised literature is used for the competency extraction stage.

Also, literature analysis showed that the latest technology to deal with the information overload problem for selection tasks is job recommender systems to overcome complexities of matching between graduate's desires, competencies from bachelor's programs and organizations' requirements.

From above, contributions of this research orient to improve the functionality of e-recruitment process.

As described, LATAM universities limiting systemic views about unifying competencies and their evaluation, passing through asymmetries for information and the unwillingness to adapt to the market may indicate a relevant need to achieve personalization and optimization of the HEI's offered services that represents a reputation increment.

In this case, implementing an intelligent job recommender system could benefit graduates and organizations from AI-based systems for HR selection, by matching fresh graduates to professional competencies and capabilities required by the public and private sector.

Future enhancement and recommendations include the development of an application relying on a sample database and the information display from job offers, not only by regular platforms and mobile applications.

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Machine Learning and Student Activity to Predict Academic Grades in Online Settings in Latam

Pablo Moreno-Ger and Daniel Burgos

Abstract In the past few years, interest in applying intelligent data-mining techniques to educational datasets has increased rapidly, with goals ranging from identifying students who need further support to being able to infer or predict a student's final grade based on their behaviour during the learning process. Even more amongst students enrolled from all Latin America. This problem can be solved with solid technical approaches, but blind brute-force data analysis approaches may prove insufficient to accurately predict grades, and even if they managed, instructors may need to further understand why and how these algorithms predict specific grades. In this work, we use an experiment to better understand how different parts of the dataset influence the performance of different grade prediction algorithms. The goal is not to achieve the best possible prediction of student's individual performance in an online university setting, with premises in half a dozen Latin American countries, and with Latin American students, but rather to identify which types of student activities are better predictors of the student's actual performance.

Keywords Artificial intelligence · Machine learning · Grade prediction · Learning analytics · Latin America · Higher education

1 Introduction and Literature Review

Growing interest in applying artificial intelligence (AI) in general and machine learning in particular to different fields is yielding a new golden age for AI. Vast amounts of data and increased computational power have awakened interest in using

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large datasets in all fields, and education is one such field with great social and commercial interest.

The increasing digitalisation of educational activities has given birth to a new research area on how to leverage educational datasets to improve different parts of the educational process. This area, generally termed learning analytics, is an emerging field that has experienced significant growth in recent years, with many aspects still to be explored (Baker & Inventado, 2014; Chatti et al., 2012; Lang et al., 2017). It is characterised by the 'use of sophisticated analytical tools to improve learning and education' (Elias, 2011) and aims to help in the field of education, improving processes, detecting students who require special support, and even facilitating learning through the prediction of the students' final grades.

This analysis has a significant impact on the field of education, where researchers seek the application of big data in areas such as resource allocation, school success, and finances in education, both in schools and in universities (Peña-Ayala, 2017). However, this field has traditionally been inefficient in the use of its data (Siemens & Long, 2011). Nonetheless, most educational environments move towards blended environments where face-to-face interaction is complemented with virtual learning environments that provide additional means of interaction and information exchange (Garrison & Kanuka, 2004). In addition, the growth of pure virtual learning scenarios (such as fully online universities) provides richer digital interactions that can be tracked and leveraged to improve the educational process (Aguado-Peregrina et al., 2014; Kellen et al., 2013; Klašnja-Milićević et al., 2017).

The day-to-day activities of students in these environments generate a digital footprint of how each student engages with learning materials and activities. This footprint may include information on online test results and activity grades, as well as on how each student studies the materials, interacts in forums (with other colleagues or teachers), accesses platform resources, participates in classes, etc. Adding the student's measured performance in assignments and quizzes to the mix, this footprint can give a lot of insight into how the teaching/learning process occurs (Martinez-Maldonado et al., 2016).

This work is built from the hypothesis that the analysis of these data using machine-learning techniques can be used to predict student performance early during the learning process by comparing the behavioural patterns of current and former students (Baker & Inventado, 2014; Burgos, 2020). Such predictions could help instructors (and even students) detect early individuals at risk of not passing the course and propose specific measures to prevent failure (Dietz-Uhler & Hurn, 2013; Lu et al., 2018; Mazza & Dimitrova, 2007).

This is especially relevant in online education, where a significant gap exists between the instructors and the students, who never share a physical space (Huang et al., 2021). This makes it difficult for instructors to assess their students' level of progress during the course. A tool that pinpoints students who may need further support allows the instructors to focus their efforts better on such students. Moreover, in an ideal future scenario, the ability to predict final grades with a wide margin of confidence may be the gateway for alternative models in which final tests will not be necessary (Shute et al. 2016), where students are graded based on the understanding displayed, whilst interacting with the content.

However, such predictions require large datasets that are often hindered by incomplete data from different sources that add significant amounts of noise and may or may not contribute to the quality of the predictions (Navarro & Moreno-Ger, 2018). For example, we may consider a typical online platform where students interact with their instructors remotely. In such platforms, frequent interactions in a public forum may be an effective predictor of good grades (this is an engaged and active student), whilst frequent emails to the instructor may be a poor predictor of good grades (this a student who is fairly lost in the learning process) (Hu et al., 2014). Furthermore, whilst well-refined machine-learning approaches may be trained so as not to be confused by these patterns, educational datasets are not always large enough to allow the algorithms to self-correct and detect these patterns (Bishop, 2006).

For these reasons, before attempting brute-force approaches on educational data, we advocate for a better understanding of these data with the double objective of improving the quality of our predictions and of informing practitioners about the internal logic behind those predictions (Beygelzimer et al., 2008).

The goal is not to achieve the best possible prediction, but to gain a deeper understanding of the noise and complexity within the dataset before attempting actual high-performance predictions. For this, we explored the relationships hidden in the data to understand how each data subset influences these predictions. An informed comparative study of the predictive models generated for the combination of different factors was carried out based on the available knowledge on how different data subsets perform (Mubarak et al., 2020).

2 Materials and Methods

This work aims to serve as a basis for the construction of robust teacher support systems to monitor the expected performance of students. This, in turn, would allow an early intervention to reorient students who require additional support, providing information that would otherwise be difficult to obtain. The work is structured around a study based on user interactions in a real-world online education system using data from a course at Universidad Internacional de La Rioja (UNIR), an online university with premises in Spain, Colombia, Ecuador, México, Perú, and the United States offering online education for international students, who come from all over Latin America and other countries worldwide, where also Latin American students are enrolled from.

A new tool for grade prediction (GradeInsight) was built for this study. The GradeInsight tool loads a specific dataset, offers different options for filtering the dataset, and then attempts to predict students' grades based on former students' data. The final course grade prediction is sought from interaction data, measuring the prediction success rate at the time of the prediction from the rest of the interaction data and continuous assessment notes throughout the course.

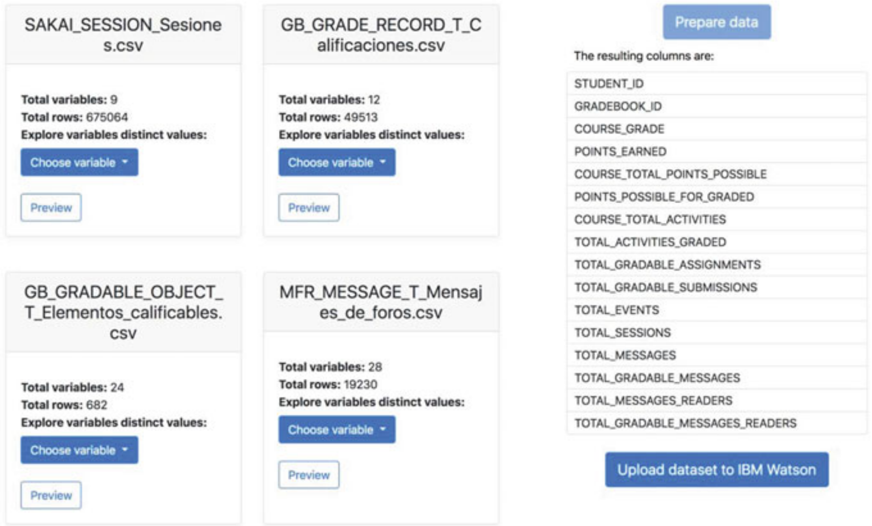

Fig. 1 The GradeInsight tool, developed for this study

2.1 Tools and Algorithms

The information contained in the datasets is analysed through GradeInsight, which uses Python and, specifically, the Pandas Library for data processing.[1] This application can process datasets from Sakai platforms and load the CSV files, provides an easy visual display of the different variables (showing the null percentage and unique values, amongst other options), and creates a final dataset based on the discovered relationships in the data (Fig. 1).

Once ready, the data are uploaded to IBM Watson Studio, a collaborative platform provided by IBM that integrates different tools focused on data analysis and specially oriented to be used by data scientists (Gabernet & Limburn, 2017). From this platform, we focus on Cloud Object Storage and Watson Machine Learning for this study.

The Watson Machine Learning service (based on Spark) allows the construction of machine-learning analytical models that are trained from the selected data (in this case uploaded through the GradeInsight application). It also offers the option to deploy those models and integrate them with external applications with an easy interface.

Prediction models can be generated from AI algorithms. The Watson Machine Learning service facilitates the generation of models automatically, offering the following estimators for multiclass classification (done in multiple categories): the

[1] The GradeInsight tool is freely available as an open-source tool: https://github.com/vicgg/GradeInsight.

naive Bayes classifier, the decision tree classifier (Quinlan, 1986), and the random forest classifier (Liaw & Wiener, 2002).

The different models generated during the analysis will be compared based on the following classification performance metrics: weighted true positives rate (TPR), weighted false positive rate (FPR), weighted precision, weighted recall, and weighted *F* measure. These measures are presented as weighted since the class, the variable to be predicted (the course grade), presents multiple values.

2.2 Analysis and Data Preparation

An analysis of the data is carried out prior to the application of the algorithms to determine and better understand the information contained in the datasets. This allows them to be cleaned as well as the subsequent execution of the algorithms on the most appropriate variables.

The data come from four editions of the MSc Programme in Cybersecurity imparted at UNIR, extracted from the Sakai learning platform (Farmer & Dolphin, 2005). The datasets are unstructured, but anonymised.

The data analysis is performed based on previous knowledge of the platform as well as the evaluation methods of the university and the elements that directly influence the grade, such as the points obtained in the continuous evaluation. The datasets are uploaded to the GradeInsight application, and their content is analysed. The application then cleans the data and prepares a single dataset that groups together the available information to predict the final grade.

The analysis reveals the relationships amongst the different attributes and datasets, facilitating the selection of attributes to incorporate in the study, summarised in Fig. 2.

The next step is to remove all the exam grades since these have an important weight on the final grade and therefore miss the entire point of the experiment. Also, the frequency of access is not reported for each specific course in the programme; therefore, the total frequency is split equally amongst all courses (which may be an oversimplification of reality). Other available data are the total number of messages in the forum, direct emails, access to assignments, actual delivery of assignments, and access to the online materials from each course.

All these transformations and pre-processes are automated by the GradeInsight tool, which then uploads the sanitised dataset to Cloud Object Storage. Afterwards, the tool launches the Watson Studio platform for the next steps (Fig. 3).

2.3 Modelling

At first glance, it seems that the more the information, the better the prediction, so all possible variables should be selected. However, we want to demonstrate in this experiment that this is not always the case. Not all variables influence the target

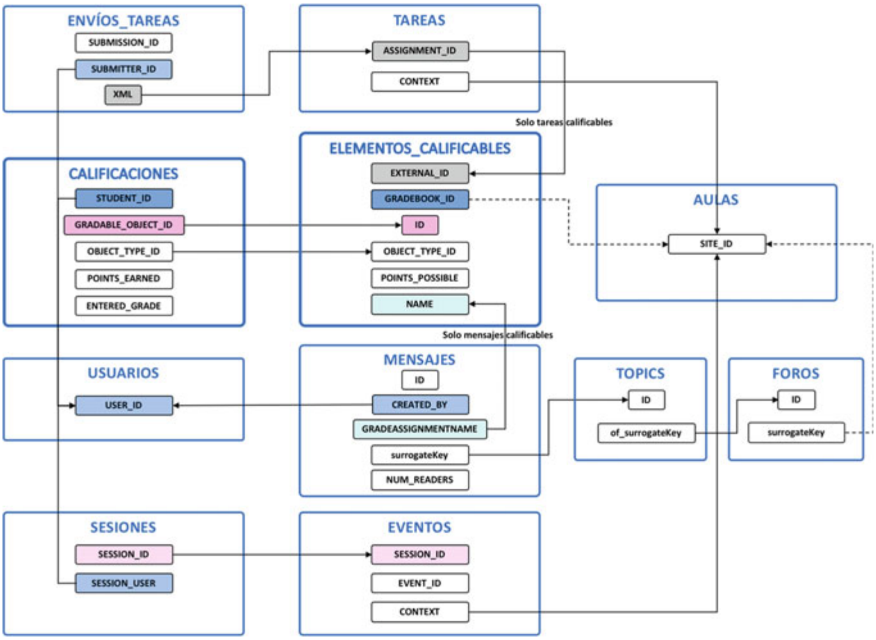

Fig. 2 Diagram highlighting the relations amongst variables in the sample dataset

variable in the same way. Some variables are completely independent of this and can even spoil the prediction, whilst other variables may generate an excessive overfit, increasing precision on the training dataset but not in the future datasets.

We want to determine the best combination of variables that describe the behaviour and results of the students' actions to predict their success or failure. The dataset generated after the data analysis can be classified into five groups:

- Partial scores: These are the scores from small activities and assignments. They are weighted in the final grade.
- Group activities: These involve participation in collaborative tasks—such as discussions, teamwork, and graded forum discussions—but exclude their partial scores.
- Assignments: These involve the level of engagement with the assignments module. This includes both the number/frequency of deliveries and the overall engagement with the module (reading the problem statement, checking for updated grades, resubmissions before grading, etc.).
- Sessions/events: These pertain to overall engagement with the virtual campus (access to the materials, recorded sessions, instructional videos, etc.).
- Messages in forums: These pertain to overall engagement in non-graded forum discussions (posting content, reading posts, engaging with other students, etc.).

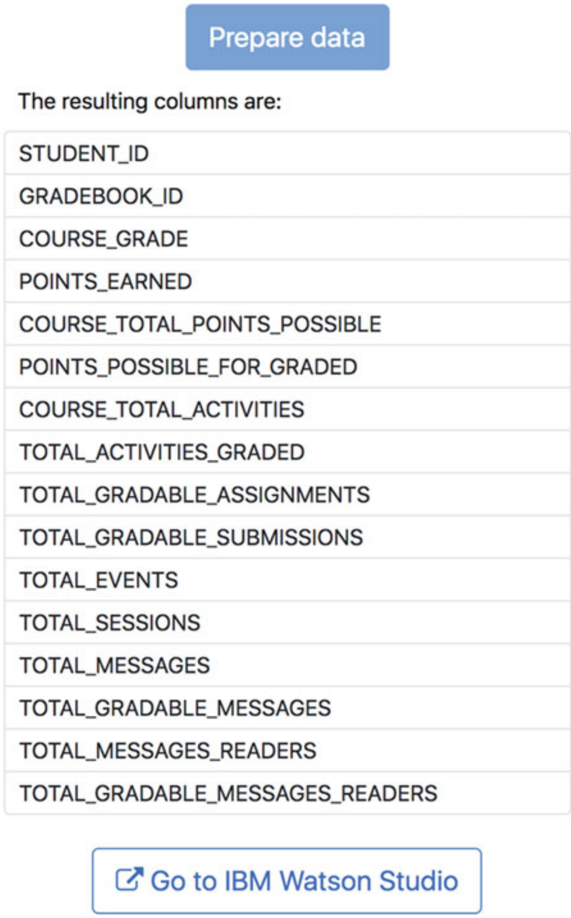

Fig. 3 Outcome of the GradeInsight tool after the construction of the dataset

We begin by generating a model with the complete dataset, and step by step, we selectively exclude variables, compare results, and draw conclusions about them. The model is generated with a training set of 70%, a validation set of 15% (which measures the precision of the model), and a holdout of 15% (which validates the model). In each iteration, the model that yields the best results is selected based on the values of the metrics for each estimator.

3 Results

The process is performed for different combinations of variables, but uses the prediction capability as a baseline when using the full dataset (Table 1).

Table 1 Baseline grade prediction using all variables in the dataset

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	0.375	0.375	0.34375	0.35714	0.375
Decision Tree Classifier	**0.75**	**0.15**	**0.725**	**0.70625**	**0.75**
Naive Bayes	0.25	0.27857	0.1875	0.21429	0.25

Note The best result is highlighted in bold

After establishing this baseline, four different stages are performed to gain a better understanding of the model.

3.1 Stage 1: Full Category Exclusions

In this stage, we analyse the results, removing one category each time. The overall decrease in performance indicates the importance of the category on the overall prediction.

Amongst all the categories used in the experiment, our first candidate for removal is the aggregation of scores from individual and group assignments since these are weighted in the final grade. As expected, the performance of the predictions drops, as observed in Table 2.

We subsequently remove the variables related to group activities (Table 3), assignments (Table 4), sessions (Table 5), and forum participation (Table 6).

After this round of experiments, we have an initial idea of the influence of each category. As expected, the greatest losses are related to assignments and partial scores. It is, however, remarkable that such losses are found when we exclude activities in the assignments module, even though the partial scores are weighted into the final score. This hints that students' active engagement with their assignments is a better

Table 2 Grade prediction excluding variables related to intermediate scores

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	**0.5**	**0.24286**	**0.5**	**0.5**	**0.5**
Decision Tree Classifier	0.375	0.14643	0.375	0.375	0.375
Naive Bayes	0.25	0.27857	0.1875	0.21429	0.25

Table 3 Grade prediction excluding variables related to group activities

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	**0.54545**	**0.20657**	**0.58485**	**0.5303**	**0.54545**
Decision Tree Classifier	0.54545	0.36768	0.57576	0.55524	0.54545
Naive Bayes	0.45455	0.33636	0.60606	0.51282	0.45455

Table 4 Grade prediction excluding all variables related to tasks and assignments

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	**0.46667**	**0.12809**	**0.43333**	**0.42222**	**0.46667**
Decision Tree Classifier	0.26667	0.16527	0.14444	0.18095	0.26667
Naive Bayes	0.26667	0.17925	0.26667	0.24889	0.26667

Table 5 Grade prediction excluding all variables related to sessions and events

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	0.54167	0.25119	0.60556	0.50972	0.54167
Decision Tree Classifier	**0.625**	**0.18571**	**0.62698**	**0.61783**	**0.625**
Naive Bayes	0.20833	0.29762	0.14904	0.17271	0.20833

Table 6 Grade prediction excluding all variables related to forum participation

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	**0.5**	**0.25974**	**0.65625**	**0.47208**	**0.5**
Decision Tree Classifier	0.375	0.31071	0.46964	0.35985	0.375
Naive Bayes	0.375	0.22143	0.55398	0.41468	0.375

predictor than the actual scores of those assignments. In turn, overall engagement with the platform (login frequency) is less relevant.

3.2 Stage 2: Exclusion of Partial Scores

After Stage 1, scores and engagement with the assignments module were the most relevant predictors of student performance. Between them, scores are the poorer predictor since these are partially weighted in the final grade. In Stage 2, we attempt the same segmentations, but always exclude the partial scores. This yields predictions excluding scores and group activities (Table 7), scores and engagement with tasks/assignments (Table 8), scores and sessions (Table 9), and scores and forum participation (Table 10).

Table 7 Grade prediction excluding all variables related to scores and group activities

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	0.41176	0.31946	0.30481	0.34641	0.41176
Decision Tree Classifier	0.23529	0.26305	0.23137	0.23127	0.23529
Naive Bayes	**0.47059**	**0.27828**	**0.51961**	**0.43045**	**0.47059**

Table 8 Grade prediction excluding all variables related to scores and assignments

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	0.41176	0.36561	0.19216	0.26203	0.41176
Decision Tree Classifier	0.29412	0.28326	0.4902	0.32696	0.29412
Naive Bayes	**0.41176**	**0.31946**	**0.36364**	**0.36601**	**0.41176**

Table 9 Grade prediction excluding all variables related to scores and sessions

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	0.35294	0.35038	0.23039	0.27554	0.35294
Decision Tree Classifier	**0.47059**	**0.17541**	**0.57843**	**0.49257**	**0.47059**
Naive Bayes	0.35294	0.37345	0.2368	0.27311	0.35294

Table 10 Grade prediction excluding all variables related to forum participation

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	**0.58333**	**0.38333**	**0.44792**	**0.5**	**0.58333**
Decision Tree Classifier	0.5	0.38182	0.5	0.5	0.5
Naive Bayes	0.25	0.42273	0.4	0.30556	0.25

After this stage, we found a remarkably significant result achieved by excluding engagement in forum discussions, challenging the notion that active and highly motivated students participate more in these discussions and eventually achieve higher grades.

3.3 Stage 3: Best Individual Predictor

The previous stages provided different results that point towards the most relevant variables in predicting student performance. As observed in Stage 2, forum participation is the least accurate predictor, which suggests that it may actually introduce noise in the model. In contrast, engagement with the assignments module seems to be the best predictor. To validate this, we performed one further test exclusively using engagement with the assignments module (Table 11).

Table 11 Grade prediction excluding all variables except assignments

Estimator	TPR	FPR	Precision	F-measure	Recall
Random Forest Classifier	0.33333	0.42828	0.33333	0.32479	0.33333
Decision Tree Classifier	0.41667	0.33182	0.43333	0.40278	0.41667
Naive Bayes	**0.66667**	**0.28889**	**0.5625**	**0.60952**	**0.66667**

The result is relatively strong, better than that of considering all the data except the scores.

4 Discussion

The outcomes of the different stages provide insights into how each variable and category influences the result when predicting grades.

In the first stage, the model generation is based on the complete dataset. This approach establishes a baseline to support the comparison. As expected, the accuracy of the model is the highest we can obtain. The subsequent analysis, excluding a single group of variables each time, shows that all the attributes influence the prediction of the final grade to a certain extent, proving that the values for the TPR metric are lower than those of the first model for all exclusions.

However, we observed one model whose performance is closer to that of the first one, which leads us to conclude that information on sessions and events has the least impact on the final grade. On the contrary, tasks and submissions seem to have some weight over the prediction.

Since all these results are heavily affected by the presence of the partial scores, in the second stage of the experiment, we studied the influence of the scores on the prediction. The importance of this group of variables was expected before the experiment was carried out since these scores are part of the same score we are trying to predict.

After excluding the scores, we find that the weighted rates of the true positives start to become similar. At one end, we find that forum interactions have a negative impact on the quality of the predictions should the score be removed. This is different from the first stage, where the group with the worst prediction was that of sessions and events, which improves the prediction. This suggests that forum participation may not be a good source of information and may have caused some overfit in the first stage when used along with the partial scores.

At the opposite end, we have the information about assignments, whose exclusion along with the score produces a model with the worst prediction so far, as with the first stage. We conclude, therefore that the information about assignments and submissions has a significant influence on the prediction of the final grade.

We also observed the impacts of sessions and events. The exclusion of the former produces a more precise model than that corresponding to the exclusion of only the score, which shows that this variable, by itself, worsens the prediction once the score is excluded. On the contrary, we find that the exclusion of the events generated, whilst the student is in the platform worsens the prediction regarding the exclusion of all information about events and sessions, in addition to the score. This suggests that the variable of events in the prediction has a greater influence than that in conjunction with the sessions. This behaviour seems to respond to the fact that the student's access to the virtual campus does not necessarily impact on his grade since he could only access information to consume it, such as delivery dates, information about the subject, etc. However, the events reflect the student's specific interactions with the platform, such as posting messages in forums or sending homework. Such interactions reflect the student's interest in the subject.

The third model validates the separate notions from the previous stages, where we proposed a final model and predicted that it would perform better than any other combination (always excluding scores), and we confirmed this prediction.

5 Conclusions and Future Work

In this work, we present a detailed experiment aiming to understand how the different categories of student interactions affect the possibility of predicting the student's individual performance in an online platform from an online university, with premises in half a dozen Latin American countries, and with Latin American students enrolled from all over the sub-continent and abroad. We did not focus on achieving the best possible predictions. On the contrary, many optimisations would obviously be required for achieving high-prediction rates, such as segmenting the dataset according to different courses, editions, instructors, or student demographic data.

In this stage of our work, our goal is not to achieve the best prediction score but to gain a deeper understanding of how such predictions would work, which data are useful, and how we can approach this problem in a human-friendly way. We do not put aside the human component since we are dealing with an inherently human trait (learning) led by well-trained professionals (instructors) that facilitate their work rather than obscure it.

The experiment is supported by the development of a specific open-source tool, GradeInsight, which should be easily generalised to use other datasets from the Sakai learning platform by other institutions. This application has greatly facilitated the data analysis and has been crucial to identify the relationships amongst the different variables.

The application of Watson Machine Learning services in the field of learning analytics is also a relevant addition since not many studies in this area make use of these services. The integration with Watson Studio has the advantage of working server side and allowing external access (for example by an application to support instructors in their work). In addition, it allows the model to be automatically fed with new information to refine the prediction.

Whilst the conclusions presented in this article are for a specific dataset and relationships amongst the data, the study presents tools and methodologies that can be extended to other datasets, requiring the implementation of small changes. However, the data come from a specific degree from a specific university with a specific instructional model. The approach must be further compared with alternative datasets from third parties to ensure that the conclusions can be extrapolated.

A further limitation for third parties is that this type of study is only applicable when sufficient information is available, such as historical information of the same course over time, considering the risks that this entails because of data inconsistency and changes in teaching and evaluation methods.

These results can also be the base for the creation of early intervention tools for student support once the predictions are refined and adequately segmented. Once the optimal model has been selected, the model can be published to obtain predictions and fed with new data (through the Watson Machine Learning interface deployed as a web service). An application could be developed for this purpose, which would present an interface to the instructors, allowing them to observe predictions for different students along with suggestions on how to support those students.

In summary, the experiment described in this article presents a methodology to identify the most influential factors in the final grade of the student, making the development of informed predictions possible for their later incorporation into instructor support systems. This work lays the basis for new studies and for the development of systems incorporated into educational processes.

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Statements on Open Data, Ethics, and Conflict of Interest This research work was carried out following strict data protection guidelines. All personal data in the dataset were eliminated and substituted by anonymous identifiers using non-reversible cryptographic algorithms. The protocols and guidelines for data protection were checked and approved by the data protection officer from the university. The educational dataset used to support the findings of this study is available from the corresponding author upon request. The GradeInsight tool is freely available as an open-source project: https://github.com/vicgg/GradeInsight.

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