University Digital Transformation Intelligent Architecture: A Dual Model, Methods and Applications

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Abstract— **Digital Transformation (DT) Inside Higher Education (HE):** *In the new era, on the way to the IV Industrial Revolution corporations of all classes, are focused on the massive and optimal practice of ICT in different organizational plans including human talent, organizational configurations, processes, inputs, outcomes, services and obviously the industry model. Nowadays, 70% of the top companies have robust DT Teams, and 40% of them are driven by high ICT and Artificial and Computational Intelligence (AI, CI). In other hand, very few Colombian Universities (U) have undertaken the problem of competitiveness in HE, much less have attempted to face the IV Industrial Revolution and take the jump, thus suffering a tremendous disappointment due to HE obsolescence. The U should play an important role in the reduction of the digital gap, and even more, must design new programs that face the formation of digital talent (i.e. Cyber-programmers Professional Technicians) that is required in this era, or we will be late again to change.*

In the recent ICT International Congress in Latin America[1], numerous national cases of DT were presented from companies, but, unfortunately, not a single case from HE. ¿Will the Colombian computerization case be replicated, which was left to the discretion of transnational computer elites? The DT of U, implies necessarily the cognimatics (the informatics for the Knowledge Society) of all the companies and their social insertion in this journey...

University Architecture: Enterprise Architecture (EA): Architecting implies the organization of a system of subsystems (SoS) or constituents to obtain better and/or new functionalities. If any piece is knowledge-based, an intelligent performance is obtained. The architecture-multilayer approach is a SoS one, that ensures compliance with government policies, procedures and standards, in a highly complex establishment with intellectual capital and intelligent processes, which is a usual status quo in an academy institution; defines the subsystems at a higher level, where a system is made-up, and with the protocols by which they communicate.

EA and University Architecture provide an industry 360• vision map, and organization structure for business and technological changes. EA is used as a system overall configuration of subsystems or components organized in layers, where each one describes an ordered audience of structures and common functionalities assembled by a purposeful criterion inside the HE institutions.

As purposes we present a succinct outline of our architectural DT model of the digital university transformation. The pillars of the architecture are: finance, innovation and investigation, entrepreneurship and social projection; recognizing from the start, that knowledge has its ethos in the U; they correspond to:

1- Productive ecosystem of the DT.

2- DT that enhances the knowledge and innovation in the universities for the habilitation of the digital capacities throughout the institution.

3- A new economy that requires **technology transformation** *also supported on entrepreneurship.*

4- New DT human talent required by the new IA and knowledge industry. The student hyper-personalization by competences and skills, bio-data, socioeconomic conditions and family composition, is required.

We discuss the basic and conceptual aspects, and methodological dimension for the DT, applying some intelligent constructs that we have developed and documented during the last 10 years at FESSANJOSE[2] leading the DT in HE.

Keywords— *Digital Transformation, Higher Education., artificial intelligence, Strategy Map.*

I. INTRODUCTION

The DT seeks to improve significantly the *productivity*, *competitiveness*, and *quality of HE* (higher education) institutions. DT is an accelerated evolution. It is also revolution because of its radical and structural implications in people as in the infrastructures of the institutions, that also demand new model of *education* and also new U *business* models.

The term transformation refers to the action or procedure by which something is modified, altered, or that changes its pattern while maintaining its identity.

This requires accepting that the potential of DT is very aggressive: there is no time for an institution to take the position of "wait to see what will happen" or "wait to know what other institutions do": it is more possible to work *pari*

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[1]   ANDICOM-CINTEL, Cartagena, https://andicom.co/.

[2]   Fundación de Educación Superior San José, U. San José, Bogotá, http://usanjose.edu.co/.

passu, with obsolete technologies, but this does not mean to get rid of all the systems to buy them and implement them again. The digital skills are no longer the simple plus for an institution: they are imperative and constitute the set of DT strategies that support the governance of the ecosystem and of the digital activities on the components, in order to encourage excellence in the digital university operationalization.

A. DT General Purpose

The general purpose is to extend the welfares and benefits of digitalization and its engineering in the whole university organization, to achieve better competitiveness, academic and administrative productivity and high quality, with the support of the academic and administrative transformation strategies as a whole, as mentioned towards a reinvented model of HE based on excellence, accompanied by a modern U business model.

B. Specific Objectives of the DT Tool

The specific objectives are to:

- Digitize all curricula in terms of competences vs. objectives of the same curricula, measuring their impact on the universal knowledge of each subject with their units of measurement: academic credits.
- Make self-assessment of the institution's products as one of the instruments of migration and continuous improvement towards High Quality Education (HQE) that allows defining strategies for the reduction of fixed and variable costs.
- Quantitatively analyze the product portfolio as impact of the research projects and other activities of social projection.
- In the same way, analyze the relevance with the research lines and the results of academic and administrative management. These analytical-deductive efforts should enrich all efforts towards HQE, achieving an internal competitive institution as well as externally.

II. THE METHOD OF DT

Our methodology covers the use of multiple paradigms ranging from information engineering, modern software engineering, data, information and software architectures, knowledge engineering with artificial and computational intelligence, and obviously *big data* (BD) and *machine learning* (ML)

The pedagogical model is located within *learning analytics* (LA) within the paradigm of learning required by the 4th Industrial Revolution

The strategic planning of the DT includes the determination of the solution system prior to the fine-tuning of the objectives to be developed, the detailed quantification of the physical, human and technological resources, the definition of the security aspects on the Internet and the *strategic map*.

The study of the system for the diagnosis of the DT, includes the engineering of requirements and processes. The design involves the proven specifications of the system through evolutionary prototypes. The construction of the system is based on tools for software development of 4th and 5th Generation, such as the Qlik tools[3].

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[3]   www.qlik.com.

Knowledge engineering is used to represent educational/administrative knowledge and reasoning systems, organize the knowledge bases, and for their distribution and communication, widening the bandwidth through hypermedia for fluid communication inside and outside the organization.

The method aligns and synchronizes all the corporate strategies, the HE institutional educational project (HEI), and the digital transformation strategies, taking into account the different normative and non-normative scenarios facing the 4th Industrial Revolution.

III. DT ECOSYSTEM

A. Concepts and Implications

The Ecosystem is determined as a network of agents (institutions of HE -HEI) accredited or not, that are articulated around the DT from the needs of the country, that respond to the characteristics of the HE context for increasing the productivity of students, teachers, academics and institutions, to finally develop knowledge, based on the substantial improvement of HE COMPETITIVENESS that integrates all its levels without exclusions, for the socioeconomic and productive development of Colombia.

The digital ecosystem defines a new social, industrial and economic impact context resulting from the massive adoption of digital technologies within universities. The digital ecosystem involves three dimensions: new modes of information production, knowledge and content, different social behaviors related to the use and consumption of goods, and a more important economic and social impact than information and communication technologies considered in isolation.

B. Ecosystem Dimension

1) Dimension of Digital Culture: the focus of a university towards digitally driven innovation, and how it empowers employees (teachers, staff) and in general all those involved (programs, parents, families, authorities, etc.) with digital technology.

2) Organizational Dimension: how a university is aligned to support the DT strategy, governability and execution. It includes the governance of the ecosystem.

3) Technological Dimension: the use and adoption of enabling technologies and the new or emerging technologies that are considered.

4) Perspectives and Insights: How well does a university company use user data and what does the university do to measure success and internalize the DT strategy?
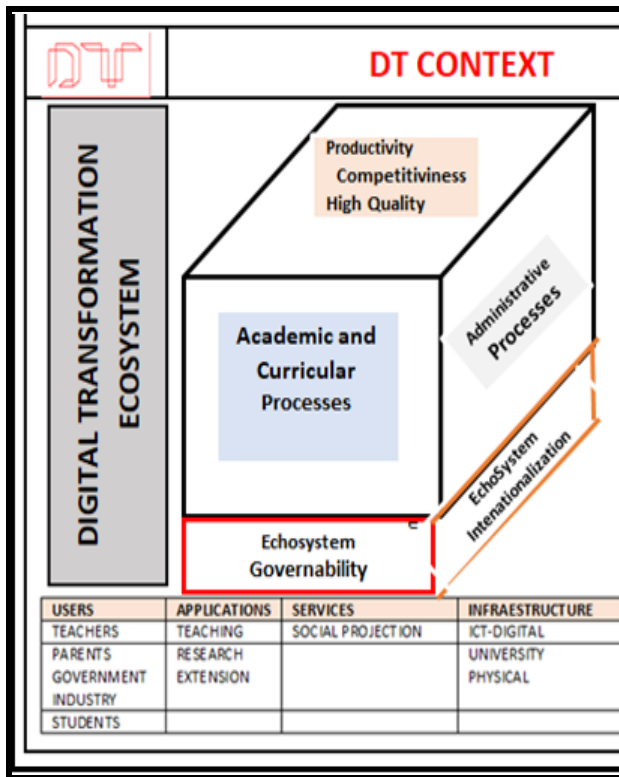
Fig. 1. DT Context

C. Advantages of the Governability of the Ecosystem

The ecosystem for the DT of the HE contributes to the continuous improvement of its quality, through research, experimental development, technological development and/or innovation with solutions to the needs of the country. Governance guarantees its permanent evolution towards digital excellence.

Short term:

a. It consolidates the capacities of research, experimental development, technological development and/or innovation.

b. It contributes to the improvement of the formation of the new and future digital talent at all levels the HE is built, to compete in the global society, pave the way to the 4th Industrial Revolution, survive successfully in the Knowledge Society.

c. It improves the visibility and the positioning of the institution at an international level.

d. It contributes to the improvement of the institutional productivity through the digitalization and/or robotization of the organizational and academic processes, and

e. It evolves more than proportionally, the seedlings of research and experimentation, accelerating the training of young researchers.

Long-term:

a. It contributes to the significant improvement of the productivity and competitiveness of the country's education sector through the generation of a portfolio of products and services, e. g. research and innovation processes.

b. It collaborates with the cognitive and digital articulation/coherence between the national and international HEIs with the other productive and social sectors of the Colombian economy.

IV. MOTIVATORS AND DRIVERS OF THE DT: WHAT WAS DECIDED TO CHANGE?

1) New expectations of paradigm shift and change of era.

2) Insufficient governance of the desertion and permanence of students, changed by the development of governability with a mathematical-computational model, with explicit policies, which were incipient and improvised.

3) The institutional policies, understood as an art of expressing positions in front of problems, were improvised and *ad hoc* policies.

4) The management and engineering of knowledge towards the promotion of the *consultancy* and the *generation of knowledge* were unknown: until 2008 there was no research. The *research seeds* in practice did not exist.

5) Need for the *development of competitive programs*, including financial sustainability.

6) It is historically the most vulnerable part: the precariousness of the salaries of teachers and researchers that has left much to be desired.

7) Need for *digitization* and *intelligent re-engineering* of all processes.

8) Quality was incipient.

9) National *accreditation* based on qualified records of all programs, not only as an imperative but as a way to *high quality*.

10) The search for *international accreditation*.

B.   Tools for future Analysis; DT Strategy Map

Strategic maps are tools that provide a macro and simplified view of an organization's strategy, and provide a language to paraphrase communication to describe it. They constitute a graphic summary of the strategy of both the corporate and the strategy of the DT.

The Scenarios we are using for DT development: Scenario planning, also called scenario thinking or scenario analysis, is a strategic planning methodology that is used extensively in DT progress to make flexible long-term DT plans.

Environmental scanning, we are also using is one of the essential components of the global environmental analysis as a part of architecting methodology: University environmental monitoring, environmental forecasting and environmental assessment, complete the HE global environmental analysis. This global environment refers to the macro environment which comprises industries, markets, companies, users and competitors. Consequently, there exist corresponding analyses for our DT Ecosystem design (see Section III). We understand environmental scanning as 'the study and interpretation of the education political, national economic, social and technological actions and trends (i.e. IV Revolution) which influence a business, industry and socio-economic or even a total market. The factors which need to be considered for environmental scanning are events, trends, issues and insights of the different actors and stakeholder's

groups. Issues as the IV revolution is not a simple paradigm change: it is an ERA CHANGE.

C. What is my DT Strategy? Build a Strategic Map

It is a logical and complete structure that describes the strategy. It provides the basis for designing DT "new DT system with strategic management". The strategic map describes the great cause-effect relationships in the transformation of intangible (academic) assets into tangible results (portfolio). Finally, the strategic maps complement the technology that allows to measure the management in a socio-economy based on knowledge.

We present a synthesized vision of the Strategic Map, in the following Figure 2.
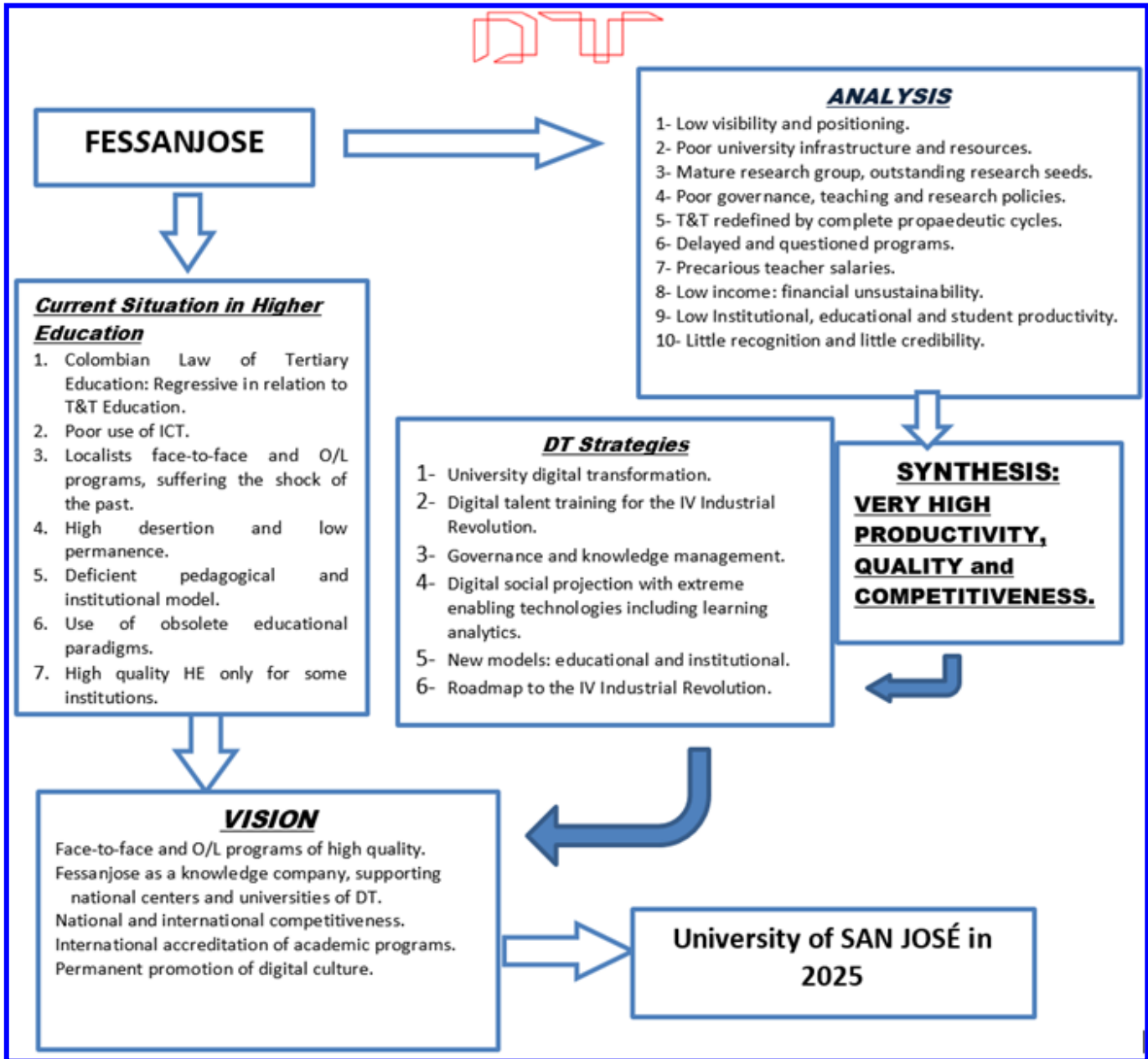
Fig.2 Strategy Map

V. DT MODEL

The DT in a HEI that has its ethos in a complex system, has numerous determinations and edges of problems.

We present different architectural views of the DT.

A. Functional Architecture of the University Digital Transformation

The architecture has dual functional aspects: academy and organization of the *intelligent educational architecture* in terms of its pillars and sustainability components.

According to the previous definitions, the DT is located in the space of the institutions' productivities, the agents, the organizational processes and the users; equally, according to the ecosystem.

In the case of the HE, the DT has 2 spaces: the curricular and the administrative.

The agents or actors are: the students, the teachers and the staff. The stakeholders are the parents, the CIO of the institution (superior council), and the government and related.

The fundamental pillars of the DT Model are:

- The enterprise, taking into account that the DT promotes the re-invention of the institution
- The research, combined with innovation, for the generation of intellectual-digital assets
- Digital talent, endowed with digital expertise to promote, implement and maintain the system towards the IV Industrial Revolution
- The required budget, given the effort needed to get rid of the past and adopt new and extreme technologies, and
- The social projection of the institution both inside and outside for the transfer of knowledge and technologies that promote the productivity and competitiveness of the country.

Model Architecture is integrated with 2 essential components:

- Portfolio analysis of digital and intellectual assets produced
- The analysis of the relevance of research policies and guidelines.

B. DT Architecture and Structure

Most of the functionalities of the DT architecture are:

- The ability to generate knowledge and innovation,
- Substantially improves the productivity of students (i.e. learning), teachers and the institution,
- Integration with the dynamics of high-quality architecture (continuous improvement) towards competitiveness,
- Support for a new Educational and Enterprise Model.
- Among the purposes is the endogenous generation of an agenda route to the IVth Industrial Revolution.
- The following figure (Fig. 3) highlights the components. Architecture has as fundamental pillars:

Funding, Research, Digital Talent, Entrepreneurship and Social Projection.

C. The Sustainability of the DT

It is presented in the following graph (Fig. 1), where it's clearly shown the duality academic space – administrative space:

1) The generation of new knowledge translates into *publications* of scientific-technical papers, properly indexed books, patents, vegetable variety, software, or new animal breed, etc.

2) The technical-scientific development and innovation, is characterized by: prototypes, industrial designs, innovations, pilot plants, technological products such as software certified by the DNDA[4] and Colciencias[5], business products, scientific-technical consulting, standards and clinical guidelines, etc.

3) Appropriation and social projection, which is related to: the strategies of communication and diffusion of knowledge (events-publications) and technologies, generation of digital contents, networks of specialized knowledge, seminars-workshops of creativity, etc.

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[4]   National Directorate of Copyright, Colombia, http://derechodeautor.gov.co/home.

[5]   Administrative Department of Science, Technology and Innovation, Colombia, www.colciencias.gov.co.
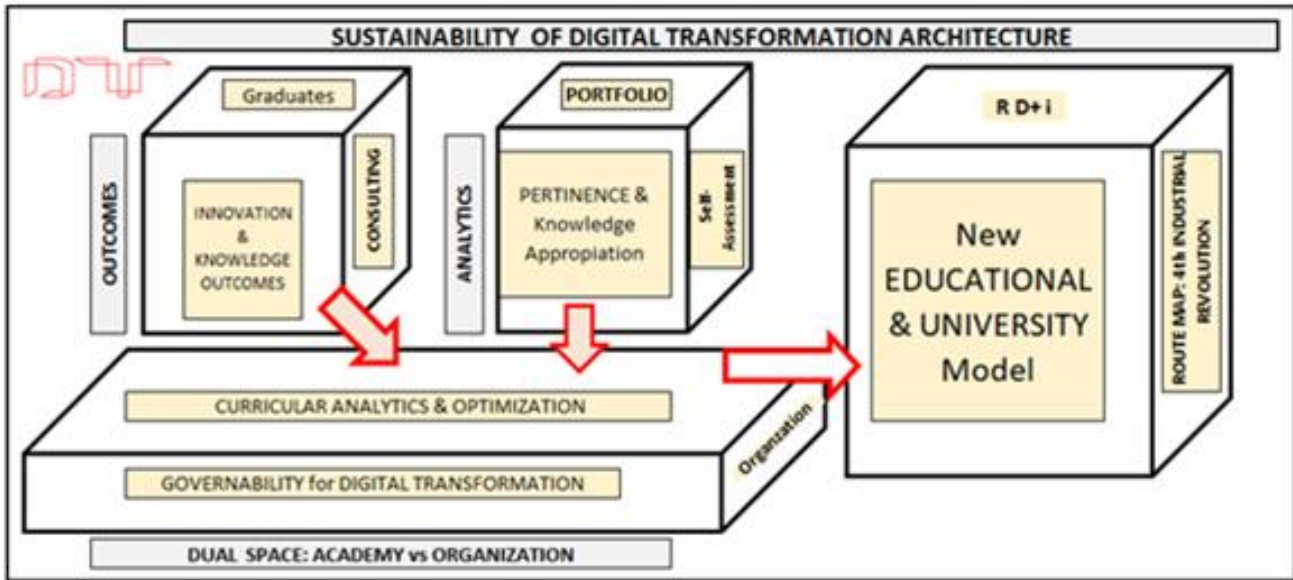
Fig. 3 DT Sustainability

D. Vision 360° of Digital Architecture

Architecture implies the organization of subsystems to obtain better and/or new functionalities based on knowledge to obtain an intelligent behavior. The architecture-multilayer approach is a system of systems (SoS), which ensures compliance with government policies, norms and standards, in a highly complex social institution with digital assets. This approach describes the subsystems at a higher level, where a system is composed, and with the protocols by which they communicate. Provides a 360° business vision map and planning framework for commercial and technological changes

Fig.4 DT Architecture 360° Vision

VI. METHODS OF DISRUPTION

A. Disruption through Digitalization

- We define digitalization as a mode that goes beyond simple process automation and looks at the application of cognitive intelligence, automation based on BD and deep data analytics and, most fundamentally, re-imagination and re-inventing the University.
- As mentioned, any workout in digitalization must start with re-imagination through which we can deliver both

robotization process and analytics-based automation to our university users.

B. Disruption through Consolidation

- We observed in the industrialization and automation how users consolidated the large number of suppliers with whom they worked at a more manageable number. Today, additional consolidation has further reduced that figure to just a few providers.

- Its focus has shifted from the unit costs to the total cost of ownership (TCO) which includes all costs on the customer side. They understand that, having maximized the cost savings of resource optimization, they now seek to optimize costs by changing ownership of capital expenditure. Customers now expect suppliers to assume the cost that is within their company and take care of the maintenance and updates.

VII. Synthesis

A. Conclusions

1) Technology can be a *disruptor or a facilitator*. The power of technology can be exploited not only through the implementation of new technologies, but also by innovating, changing the way of doing things and adapting to the new business scenario in the new era.

2) Understanding the need to transform and have a good knowledge of what the University needs to change, is important, but the key success factor lies in the implementation path.

3) The methodology or how to transform the university, is where most organizations fail. Although there is no single action plan or roadmap for all universities; we discover that agility capacity is related to positive academic-financial performance as well as the ability to respond to digital disruption. This requires that the digital speed is composed of three competences:
- The ability to detect relevant changes and trends
- The proficiency with informed decision making, supported by BD.
- The ability to make decisions based on evidences demonstrated in a timely, reliable, collaborative, and fast execution. The expertise to quickly translate decisions into action by taking risks.

4) The most effective starting point will probably depend on where the institution is today, with respect to its digital maturity, and probably should address the specificities of its commercial and geographic portfolio.

5) There is no single approach to DT among universities. There is a variety of operational models in different digital ecosystems.

6) University leaders are likely to anticipate the initial need for a DT campaign to effectively engage the digital talent and prepare them culturally for the hard digital journey.

7) The digital journey will likely come with emerging challenges that may seem overwhelming. With the enabling technologies mentioned above, the DT can follow a systemic approach supported by strong partnerships and digital talent management.

8) Collaborating with industrial partners in certain ecosystems and developing the new skills in the talent base can only facilitate the passage to nirvana or digital paradise and position the company towards greater continued success.

9) Any large-scale transformation tends to alter and uproot existing structures and deep-rooted mentalities

B. The Road Ahead: Beyond DT

1) DT should evolve as the philosophy of our life and part of the new digital culture that affects all personal, corporate, industrial, government, commercial and social orders. The internal digital culture of the organization must be constantly evolving.

2) The HE company and each professional must be willing to identify changes and transform themselves permanently: There is no goal or season of arrival: it is a long journey.

3) Continuous training is the *trigger transformer* to compete digitally and be updated on new technologies methods and their tools: it is imperative to promote digital talent.

4) Evolution as an organization for the 4th Industrial Revolution and in *people management*, so that employees can innovate, be trained digitally and encourage each one of their contributions to grow within the organization.

5) It is essential to keep the *HEI's digital strategic plan* in effect at all levels, promoting inter-collaboration.

6) There is cognitively measuring (i.e. cognitive metrics): KPI indicators are not enough.

7) We have to *evaluate, analyze* and *optimize* the implementations made for the improvement and continuous adaptation to the changes demanded by and for our users.

8) Internal and external omni-channel communication is an essential element for DT but it must be rich in its contents.

9) The strategies and tools applied in the DT suppose a competitive advantage that is profitable with an improvement in the processes (both academic and organizational), the satisfaction of those that integrate and participate in the university, and especially as mentioned, in the digital experience of the users, students, lecturers and HE community.

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