Curricula framework for a digital transformation master's in science and engineering

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Curricula framework for a digital transformation master's in science and engineering

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Abstract. Digital transformation is an interdisciplinary work that has the objective to analyze data in real-time for better decision making, where it involves the modeling and the simulation of physical-mathematical and social processes and the monitoring of machinery that using information and communication technologies. Nowadays the fourth industrial revolution technologies are the driver for this transformation and soon will be quantum computing and other physics and mathematics advances. Therefore, in this academic-scientific work, a curricular framework is proposed for a master's program in digital transformation for science and engineering; the framework follows the literature review and analysis to formulate the denomination and justification for the master's degree. The results are (i) a general three-level model as a roadmap for the specific curricular design of a master's in digital transformation for science and engineering; (ii) the recommendation that a master's program has a research focus in the two categories established by the Colombian standard (research and practitioner); (ii) finally, a political, economic, social, technological, environmental, and legal analysis justifies a master's in digital transformation for science and engineering. The research model details the phases that were carried out to characterize and identify the curriculum framework that will be the basis for formalizing the master's degree document.

1. Introduction

The world is moving forward during a large-scale technological convergence of high speed, intensity, and capacity for social, cultural, and economic change. The phenomena known as the fourth industrial revolution (4RI) and industries 4.0 and 5.0 are reconfiguring value chains, generating new products and service and business models, as well as changing education and government, increasing productivity and well-being in society. Moreover, these phenomena consider the importance of protecting natural resources and ensuring sustainability and inclusion [1-4]. Digital Transformation is urgent, because due to quantum computing, 4RI technologies will experience their own transformation in a few years and the transformations in society will be even greater. Quantum computing is the result of years of research on physical and mathematical models that completely revolutionize computer science and challenge the dominant technological models.

In physic and mathematical contexts digital transformation allows to understand and comprehend the world and its processes. It consists of implementing models that allow to explain those processes and migrate them to the digital world, where current and future technologies help to improve those processes and increase their advantages. The transformation is not only that migration from a model to the virtual,

but it must also allow an integration between the physical and the virtual, where that process continues to work in the physical world but being improved and simulated with the incorporation of technology.

Therefore, organizations need changes in their infrastructures, processes, and culture to appropriate, adopt and adapt these global trends and thus generate impact. Digital transformation results from a process in which three phases have been identified: "digitization, digitalization & digital transformation". The first phase refers to making changes from analog to digital, but without altering processes or organizational culture. The second phase involves the adoption, appropriation and use of Information communication technologies (ICT), generating some changes in the processes of the organization and its culture, but as emerging changes, unplanned consequences; and the third is a disruptive transformation, but planned and managed, a transformation that seeks an impact on business and the value chain of the organization.

The scope of this paper is the public policy of Colombia and social and culture context of San José de Cúcuta; in Colombia, digital transformation is so important and transcendental that in 2019 the national policy for digital transformation and artificial intelligence was established, according to document of the “Consejo Nacional de Política Económica y Social (CONPES)” 3975 [5] and in 2020 a digital transformation framework was published to improve relations between the government and citizens, which includes guidelines for emerging technologies, tools to measure and prioritize [6] and other official documents for the digital transformation of the state, in an articulated manner with the 2018-2022 development plan, law 1955 of 2019 and other related regulations [7].

For the above digital transformation is a professional and research challenge in all areas and levels: in business, government, education, science, art, and society. This challenge involves the synergy between several disciplines, in particular management sciences, engineering, computer sciences and other information and communication technologies (ICT) related disciplines. This synergy is achieved by expanding the capabilities of professionals, executives, and researchers, which requires universities to train human talent capable of dealing with all these processes. In this order of ideas, the challenge is to train professional capable of doing research in digital transformation, technological development, innovation, and entrepreneurship on relevant problems for the productive sector and society in the context of emerging technologies that are evolving rapidly (such as cloud computing, services computing, data science, artificial intelligence). This paper is organized as follows. Section 2 presents methods. In section 3 the results are discussed; finally, in section 4 we summarize the conclusion.

2. Methods

The research model is proposed in Figure 1, which details the phases that were carried out to characterize and identify the curriculum framework that will be the basis for formalizing the master's degree document. First a survey and focus group were done, second, we conduct the literature review, the tree of science tool (ToS) was used, which analyzes all publications and their incoming and outgoing citations and generates a citation network in the form of a tree, with root, trunk, and leaves. The slogan of this tool is "search less, research more!" [8,9].

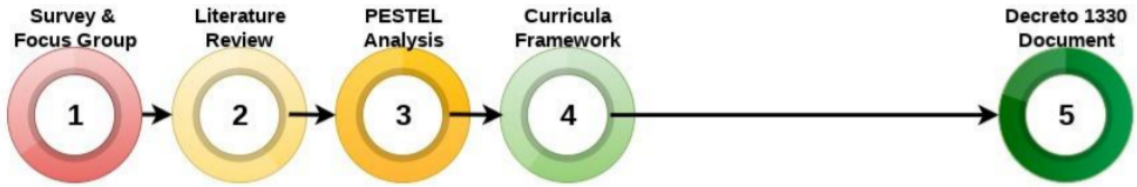

Figure 1. Research model.

Third, a political, economic, social, technological, environmental, and legal (PESTEL) framework to analyses the macro-environment (PESTEL) were done in transformation digital area, PESTEL framework is a method developed by Fahey and Narayanan that analyses the business environment from a macroeconomic perspective [10,11]. Finally, the curricula framework is proposed as the theoretical and epistemological basis of the master's program.

The research questions addressed in this research paper are: What is its origin, historical evolution, status and prospective? What is digital transformation? What is its location, disciplinary or interdisciplinary? This document shows only up to step four. Because due Colombia's laws a much more extensive document is required, and these laws prevent the generalization of the analysis and the results of this work.

3. Results

3.1. Literature review

Digital transformation is a recent topic. In SCOPUS, the oldest publication is from the year 2000, in the context of healthcare companies, within the framework of the concept of e-health, following the boom of digital companies ".com", e-commerce and e-business (e-commerce & e-business) [12]. In WoS, the oldest publication is from 2003 and shows that since the early 90s the profound transformations that are currently originating from the influence of ICT in all contexts of humanity were predicted and developed [13]. In general, the authors agree that the digital transformation has its origin in the boom of the Web (www) as a technology and of e-commerce and e-business as phenomena of industry, organizations, and society. Then ICT rapidly evolved or converged towards cloud computing and big data, originating the phenomenon of the Fourth Industrial Revolution or Industry 4.0. At present, it is moving towards topics such as the internet of things, artificial intelligence, and robotics. These technologies may be used to develop computational models for determining atomic structures, new materials, radiative properties, quantum computing, and simulations.

Digital transformation interest has been growing both in the field of public policy and the productive sector, as well as in scientific publications. This trend is clearly shown in Figure 2, which summarizes the behavior of the topic digital transformation in SCOPUS, Web of Science (WoS) and Google Trends; during the last five (5) years there has been a growth in publications and citations, which will be maintained during the next decade, according to the latest reviews published and the articles and authors with the highest number of citations.

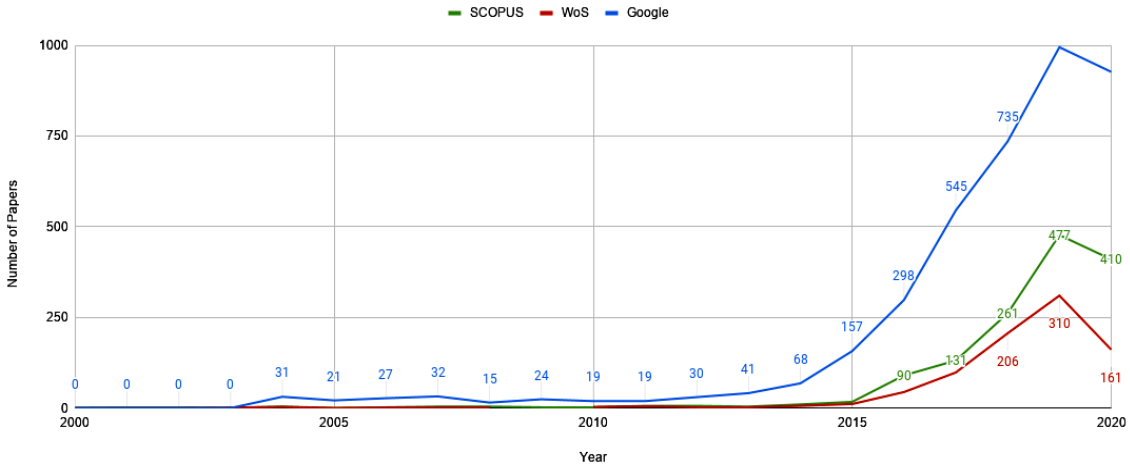

Figure 2. Evolution of digital transformation publications.

Considering the several publications about it and to filter this topic an analysis was performed using the tree of science tool (ToS). So, the origins, evolution, current state and prospective of digital transformation can be easily identified. Figure 3, Figure 4, and Figure 5 show the structure of the tree (root, trunk and leaves respectively) using only SCOPUS because it has the largest number of publications and covers WoS. The ToS filter ten (10) publications on root (see Figure 3) and trunk (Figure 4); And filter sixty (60) publications on leaves, bat only ten (10) most cited publications are showed.

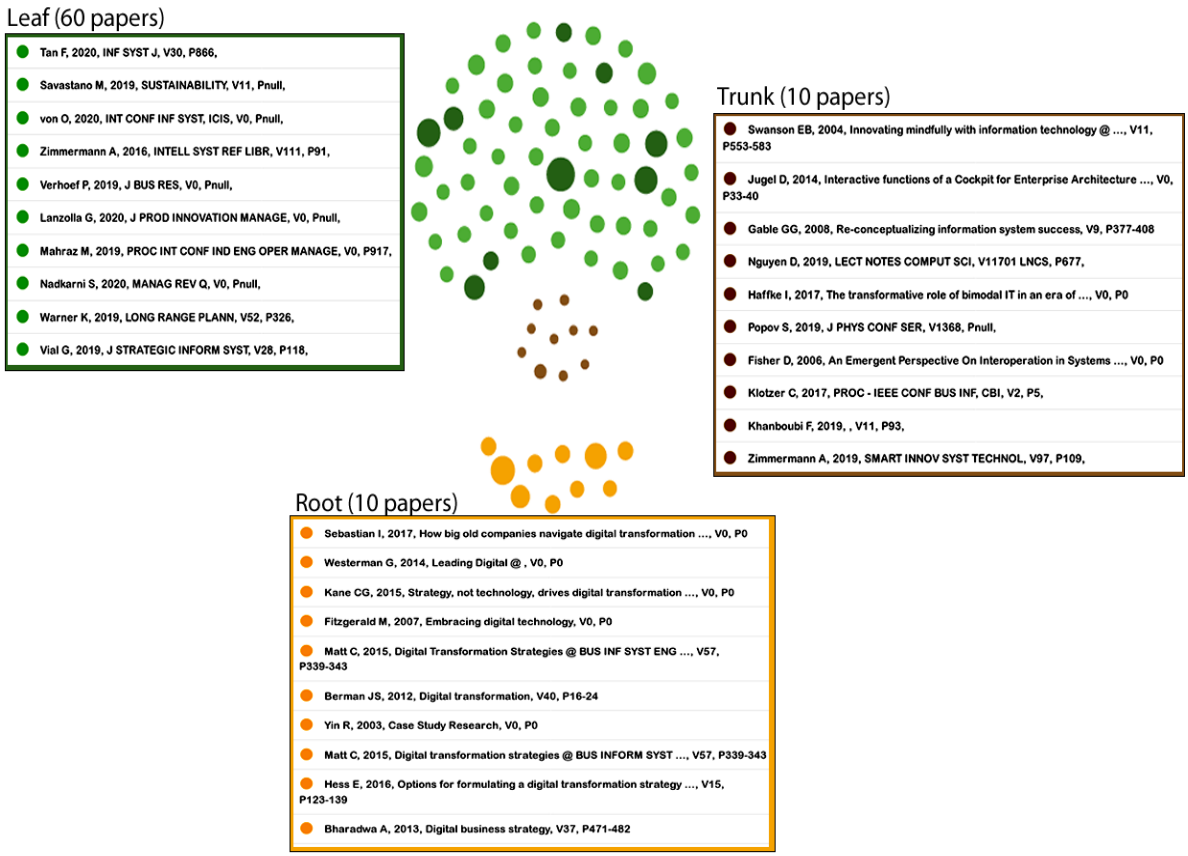

Figure 3. Tree of science literature analysis.

If the citations are reviewed, the top 3 most cited articles in SCOPUS counts (each article) with more than 300, while in WoS there are more than 200 citations. In both cases the most cited articles are from the past decade. There are publications that have been cited more than 100 times (hot papers). Figure 4 shows the citation behavior of SCOPUS and WoS publications and the recent interest in this topic is evident.

Reading these publications, filtered with the tree of science, the body of knowledge of digital transformation is obtained.

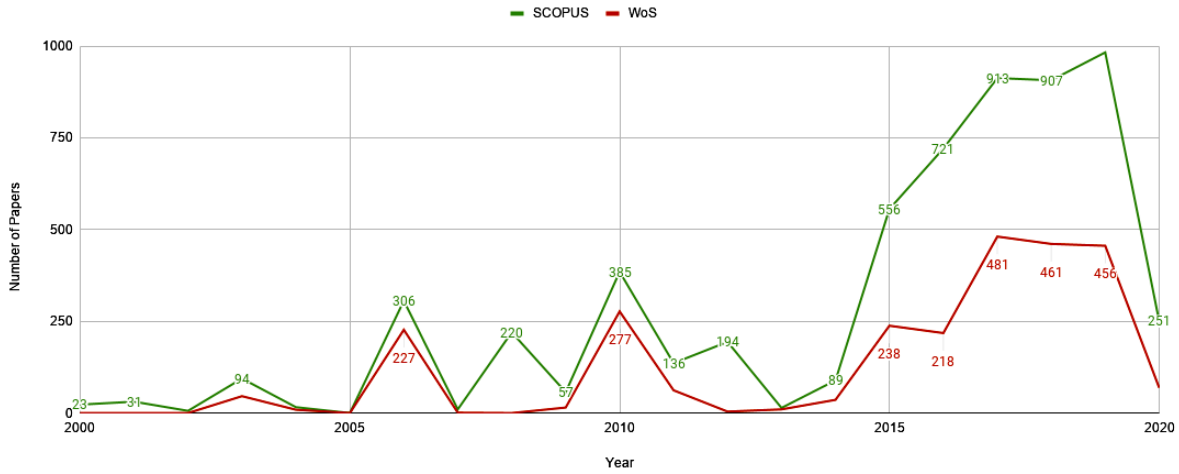

Figure 4. Citation distribution by year in digital transformation publications.

3.2. Digital transformation definition

Digital transformation can be understood as using ICT to improve the performance or scope of organizations [14]. However, the implementation of ICT is only a small part of digital transformation, as it is necessary to generate value for customers, all stakeholders, and the organization in general [15,16]. Digital Transformation changes customer relationships, internal processes, and value creation, because of its potential impact on products, services, innovation processes and business models [17,18]. These changes can occur by substitution (ICT replaces a function / process that the organization already performed), extension (ICT enhances the functionality of a process / product) and transformation (ICT fundamentally redefines a process / product) [19].

According to the above, for the master's degree, digital transformation is conceived as: "a process for the significant improvement of organizations, through the incorporation and intelligent integration of emerging technologies, linked to the organization, computing, computerized information processing and ICT in general".

3.3. Digital transformation as interdisciplinary topic

In accordance with the previous analysis, the disciplinary or interdisciplinary nature of digital transformation is now addressed. By contrasting the SCOPUS and WoS publications with the curricular approaches of global organizations Association for Computing Machinery (ACM), Institute of Electrical and Electronics Engineers (IEEE), and Association for Information Systems (AIS) among others) and their studies on trends in ICT market and the educational transformations required in the university, it can be affirmed that the digital transformation is an interdisciplinary topic. Literature shows that the 4RI and industry 4.0 demand a holistic vision, a work of synergy between several disciplines, visions, and perspectives, since this interdisciplinarity is what really originates the digital transformation in organizations and society. This can be seen in the 1473 publications in SCOPUS and the 892 in WoS. If we analyze the areas or disciplines where they publish on digital transformation, we find that it is an interdisciplinary topic, during disciplines related to business and ICT, and that it emerges in the context of other disciplines. For example, digital transformation in the health sector, in agriculture, in education (Figure 5).

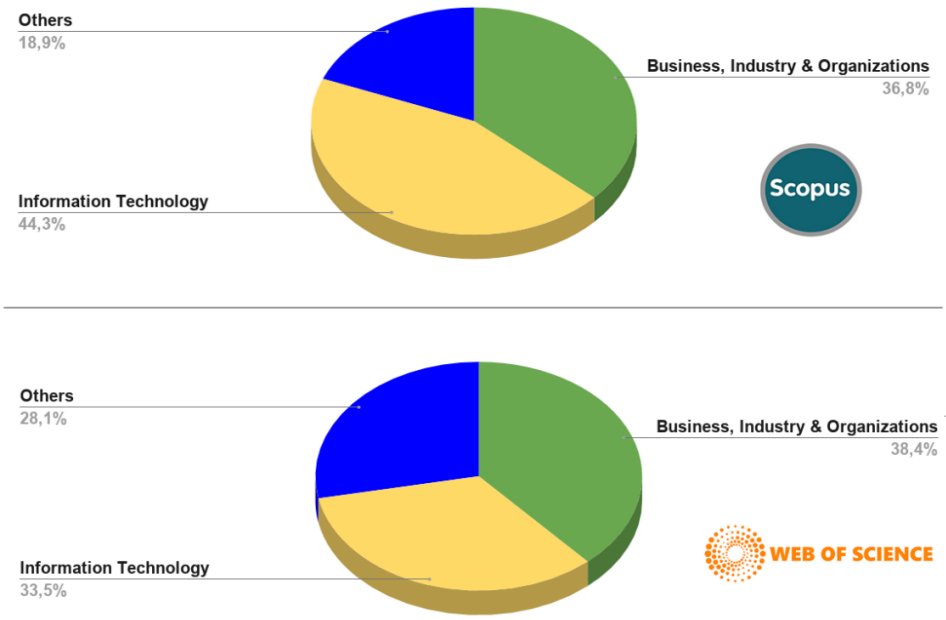

Figure 5. Digital transformation as interdisciplinary topic.

3.4. Political, economic, social, technological, environmental, and legal analysis

The Figure 6 summarize the PESTEL analysis in context of Colombia to propose a Master of digital transformation. politically and legally, Colombia has laws and national and local plans that require the training of human talent in digital transformation. In the economic sphere, organizations such as the IDB, OECD, ECLAC, among others, show that the development of countries depends a lot on digital transformation. In the social sphere, documents such as UNESCO 2030 indicate that education, science, and collaboration are key to face the challenges of the planet and humanity, and this is achieved in the context of digital transformation. Green computing is one of the examples of digital transformation; finally, technology is the backbone of digital transformation.

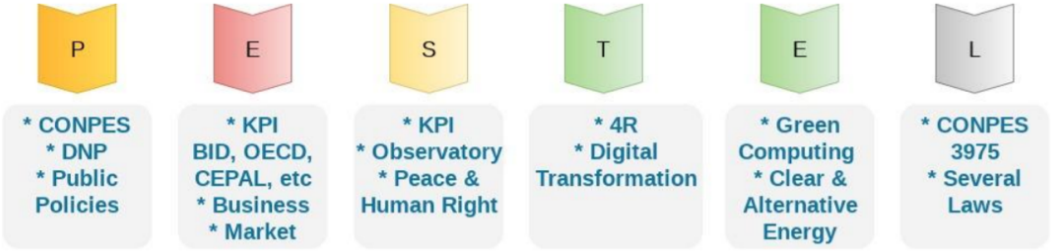

Figure 6. PESTEL analysis.

This principal contribution of this paper is a curricular framework for a master's degree program (Figure 7), which have two areas: (1) ICT, and (2) Industries and organizations. Above these areas is necessary human talent to make (3) Research, technological development, and innovation to reach (4) digital transformation.

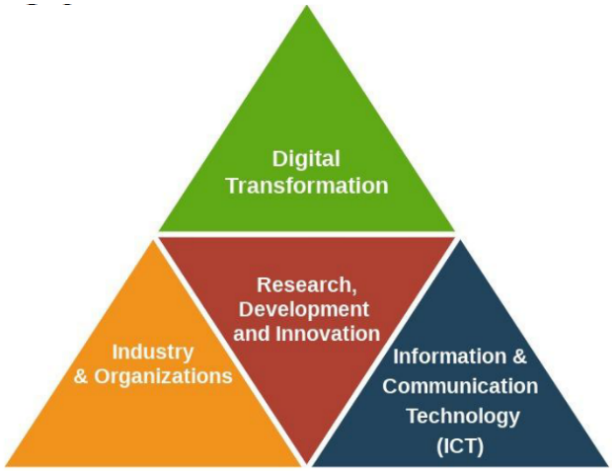

Figure 7. Digital transformation framework for the digital transformation master's degree.

4. Conclusions

This paper proposed a definition of digital transformation and show the interdisciplinary character of digital transformation that involve mainly two large groups of disciplines: ICT for digital transformation and industry and organizations. A balance between these two areas is proposed, both in body of knowledge and competences, so that a master in digital transformation is able to do research on relevant problems for the productive sector and society in general (industry and organizations), contributing to the solution of those problems and leading the digital transformation through the generation of new knowledge, technological development, innovation and entrepreneurship, in the context of rapidly evolving emerging ICT (such as Cloud Computing, Services Computing, Data Science, Artificial Intelligence), which may be applied to process of simulation, modeling development and

characterization of new materials and technologies. This proposal can be considered as the theoretical and conceptual frame of reference of the master's in digital transformation for science and engineering.

In this article a literature review is carried out following the science tree methodology, to discover and define the scientific and technological areas that define the digital transformation, which become the training axes of the master's program. Finally, a limitation for this work is that its legal, social and culture scope is Colombia. Nevertheless, the sources, analysis and results may be generalized to other countries and regions; this review use tree of science tool to summarize and simplify the process.

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