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The Impact of Artificial Intelligence on Innovation Management: A Literature Review

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Abstract: The digital transformation and its accompanying artificial intelligence processes are becoming the essential focus of the contemporaneous digital revolution. Its real impacts, challenges, and opportunities on the industry and the business environment remain unknown. In this context, innovation has become the main driver of competitiveness. Nevertheless, innovation is no longer an isolated and residual agent but a crucial mindset that should be embedded in all workers and all activities of a company, as innovation can improve an organization's performance and the employees' well-being and working conditions. In this context, the growth of artificial intelligence in the business world seems to be changing the way companies innovate and manage innovation processes.

This paper presents a literature review study whose objective is to get insights into publications that relate innovation management and artificial intelligence.

The method used in this study is based on the analysis of data obtained from the Scopus database.

As a general insight, it is concluded that AI systems can free managers from more technical and exhaustive research tasks and enhance creative processes. This way, managers can focus more on creativity applied to problem-solving and the conception and development of innovation strategies.

In terms of originality, this study aims to contribute and stimulate data-driven discussions regarding the possible impacts of artificial intelligence on innovation processes. This study also explores directions for future research.

Keywords: Innovation Management; Artificial Intelligence; Innovation Models

Introduction

The changes in society, resulting from the challenges arising from sustainability and the digital transformation, are putting a great pressure on competitiveness.

Academics and managers have long been discussing the importance and role innovation management plays in the competitive advantage and organization's growth.

Knowledge production and research within the field of innovation management is accelerating at a fast pace, while at the same time remaining fragmented and interdisciplinary. This reality creates a challenge in narrowing and keeping up with the collection of data, evidence, and studies in this specific area (Snyder, 2019).

To examine the vast amount of data published until the present, a literature review was elaborated as a research method to understand and evaluate what has been written specially in the last 10 years. This analysis is fundamental to clarify and define such a broad concept such as innovation management and artificial intelligence, so that a relation between the concepts can be more concretely established and studied. Furthermore, what are the gaps and important aspects yet to be explored or missing in the literature. At last, a review was conducted on how

artificial intelligence presence is affecting and changing innovation management procedures and models, within companies nowadays.

Data was collected mainly from Scopus. This database was chosen because of the availability of different publications' analysis regarding authors, citations, and sources. Another factor was the up to date and relevance of the available articles.

The research process was elaborated using the keywords "Innovation management" and "Artificial Intelligence" in the academic and business sphere.

1 - Literature Review

1.1 Innovation management definition

Despite the significant volume of publications available in academic research databases such as Elsevier Scopus about innovation management until the date, the year 2000 was when the number of articles about innovation started to increase more significantly. This was probably due to the growing interest of academics and firms regarding the subject and also the technological advancements. Being the USA followed by Germany the countries with more publications on the subject of innovation management.

The number of articles published regarding innovation management has continued to grow steadily in the last decade. In Scopus there were published 2013 articles related to the subject from 2016 until May 2021.

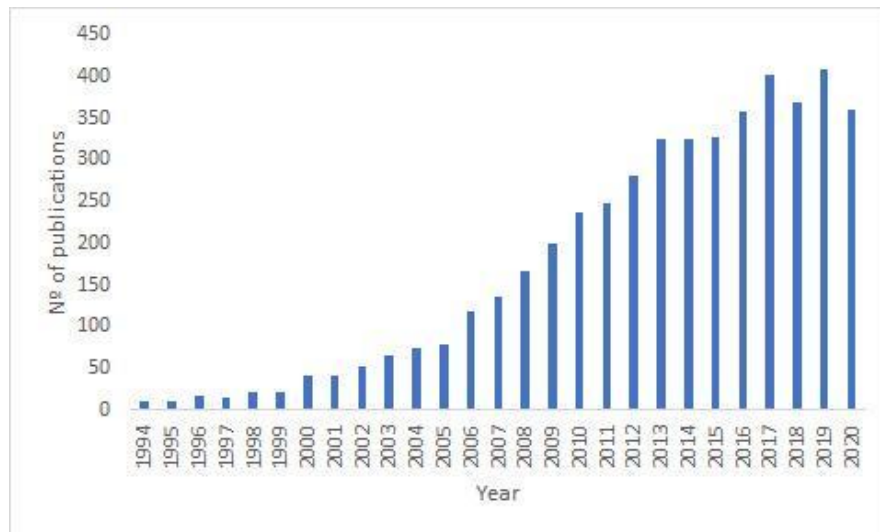


Figure 1 - Evolution of the number of articles published in Scopus throughout the years

Source: elaborated by the author

A considerable literature was found and analyzed for this research, on the subject of "innovation", its origins and history. At first, the literature seemed rich and vast but since the focus of this research is not on "innovation" itself but on innovation management models the author could verify a fragmented and diverged literature.

The lack of a generally accepted definition is partially due to the ambiguous nature of the concept of innovation itself and also the multidisciplinary nature of the field (Lopes et al., 2017). There are measures of aspects of innovation management frequently proposed that respond to some needs of both companies and researchers to understand the application and effectiveness of innovation however, this information is fragmented (Adams, Bessant & Phelps, 2006).

When analyzing innovation from the perspective of innovation management concept, there are some consensus that despite its diversified character, innovation management is an important mechanism for the competitiveness of companies and countries (Narciso, Canen & Tammela, 2018). Innovation capability can and should be conceptualized and measured (OCDE, 2018), since it holds the potential to create novelty and knowledge (Zheng, Liu & George, 2010; Lawson, & Samson, 2001). There is also the consensus among authors that innovation management has been received increasing attention in the operations management field during the last years. Academics and managers have been discussing and analyzing the definition of innovation management and its importance for the organization's growth and competitive advantage.

Innovation applied to management and organizations is much more complex than the simple meaning of "creating something new" as the definition of innovation implies and covers a considerable diversity of phenomenon perspectives. Therefore, before proceeding with the present analysis it is relevant to establish the complex and multidisciplinary nature of innovation management topic. And due to its multiple distinct layers and dimensions it is not possible to achieve one definition. However, through complementary contributions of different authors and frameworks it becomes possible to establish common innovation determinants and develop guidelines for each activity of the supply chain that are under the umbrella term of innovation management.

Another issue that remains unsolved is how to recognize what type of innovation management is necessary for each company's activities and departments. There are difficulties in establishing concrete guidelines and procedures for each of the activities. One of the reasons for this problem are the different dimensions which innovation can be addressed such as technological; organizational; process; product; among others. Besides, the differences between sustaining and disruptive innovation or incremental versus radical innovation that lead to different ways of management.

Innovation management includes changes in the "how" and "what" managers implement in preparing guidelines, creating resolutions, managing events and how they motivate individuals. Innovation is essential both at the individual level and the organizational level for the evolution of the environment of business. Innovation can be an upgrade in performance and procedures adopted by an organization or (Pfeffer and Sutton, 2000).

Before the 2000s, there seems to be a lack of consensus on innovation management as a concrete and defined discipline transversal and applicable to all activities within the organization.

Chesbrough (2003) opened the way for the open innovation model with many scholars considering that his contribution created a new paradigm for the analysis of the innovation process. Open innovation encourages companies to open up their innovation processes, giving up their closed and hierarchically rigid processes. The author defines innovation has a process of information creation only possible to be developed out of social interactions, thus companies cannot rely only on internal resources and knowledge anymore. They have to look outside and try to identify new skills and knowledge to complete their own. The ability to innovate combining internal and external knowledge is becoming one of the most critical aspects that lead to a sustainable competitive advantage (Lopes et al., 2016).

This new approach has contributed to changes in companies' dynamics, either internally (changing behaviors towards innovation, but also the way people and departments interact) and externally, changing how they gather information and relate to other organizations (Trott, 2017; Chiaromonte, 2004).

1.2 Artificial Intelligence

Despite the concept of Artificial Intelligence have started to be developed throughout the 20th century, its exponential growth happened only in the beginning of 21st century.

Scientific publications date back decades but the boom in published literature related to Artificial Intelligence started only around 2001 (WIPO, 2019).

In Scopus database, during the 1990's the number of publications regarding AI was approximately the same each year. From the beginning of year 2000 and onwards, there has been a steady growth in the number of publications per year.

This research focused mainly on literature published in the last 5 years. From 2016 to 2020 there are 129,114 publications available related to "Artificial Intelligence" in Scopus database.

However, when the research words are "Artificial intelligence definition", there are only 72 related articles published in Scopus database since 2000.

Establishing a comparison, in 2013 there were published only 3 articles related to the definition of Artificial Intelligence, whereas in 2021 there are already 26 published in Scopus database.

We can conclude that there has been a very significant growth in the number of articles published related to Artificial Intelligence in the last 20 years and.

The concept of Artificial Intelligence is very broad and not fully defined and understood in the literature, despite the great volume of articles published in a vast range of fields and business activities.

Modern Artificial Intelligence (AI) research began in the mid-1950s, with a conference at Dartmouth College that led to a great enthusiasm in the area among scientists and researchers. From that time, AI laboratories soon were created at major universities and institutes (Oliveira, 2017).

In the 1950s, the term "artificial intelligence" was originally used, to describe the simple idea of human intelligence being exhibited by machines. Although this assumption might not be very accurate, since computers use techniques to solve problems in different ways, human brain process information to solve the same problems.

For instance, a chess player AI system use speed to evaluate millions of positions per second – a strategy not possible to be used by a human chess player (Oliveira, 2017; Muthukrishnan et al., 2020).

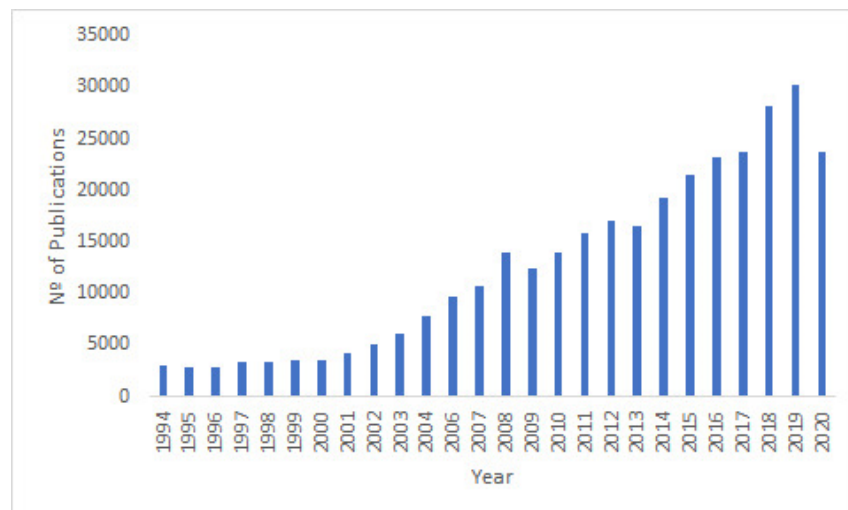


Figure 2 - Evolution of Artificial Intelligence publications throughout the years in Scopus
Source: elaborated by the author

Some authors have theorized that there are challenges for achieving Artificial *Wisdom*, because of its intrinsic nature.

The principal reason for this challenge lies in the philosophical distinction between practical wisdom and practical intelligence. Hacker-Wright (2015) explains that instrumental rationality or cleverness is getting the aims right, rather than reasoning well with a view to fulfilling aims. Skills are the instruments of rationality while practical wisdom demands to reflect about what end to follow. Therefore, an agent is wise if he can deliberate well about the final goals of the domain (Tsai, 2020).

Despite the challenges of inspiring Artificial Intelligence in human reasoning, the literature shows some degree of consensus about the use of AI in practical intelligence. Which is the construction of programs that mimic the behavior of human intelligence step by step using deduction, reasoning, planning and scheduling. Even though scientists were able to develop AI systems that perform some tasks, there are many difficulties researchers face behind the creation of models based on the human reasoning, since many activities of our daily lives are intractable and computationally hard to formulate.

Alan Turing, widely considered as the father of modern computer, anticipated some of the objections to its own AI definition present in the known Turing test.

Since the Turing test forces the computer to imitate the human behavior and it has to possess human like reasoning, nowadays researchers agree that the test has some limitations as it is difficult to apply in today most advanced AI systems.

For now, the absence of emotions can be used to differentiate AI from human intelligence even though computers might be able to interpret human emotions and feelings in the future (Oliveira, 2017; D’Acquisito, 2020).

When analyzing the literature, it is possible to verify a general agreement regarding AI being a term used as an “umbrella” that includes many sub areas such as machine learning and deep learning.

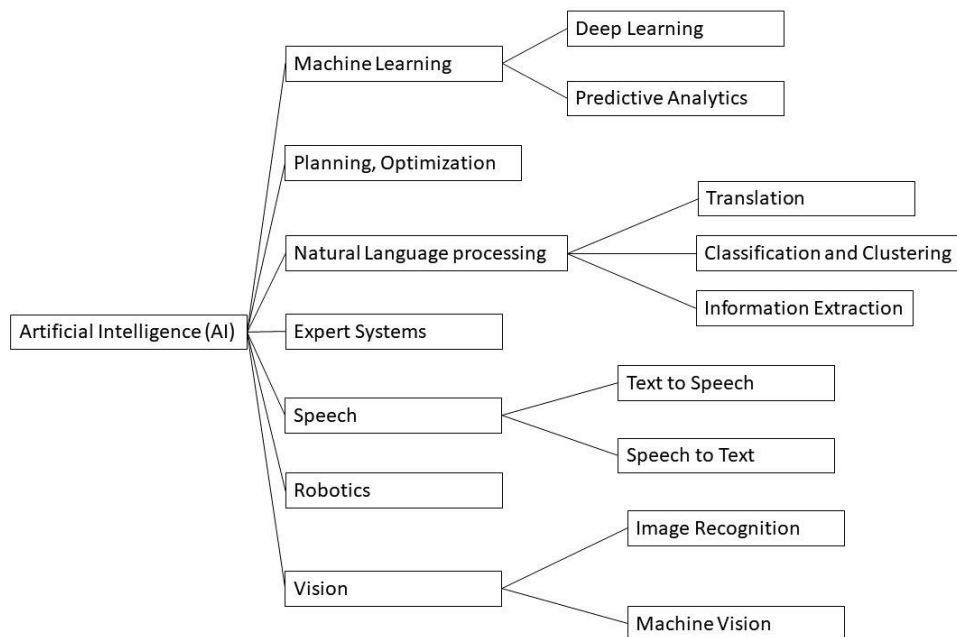


Figure 3 - Artificial Intelligence Subfields

Source: elaborated by the author

Artificial intelligence stands within the technological innovation, but it is transversal to all activities such as research and development, financial and commercial ones. These systems are

already being considered “a general-purpose technology” and will likely be an important component of future work. (Hilb, 2020; Ghosh et al., 2019).

1.3 Impact of AI on Innovation Management

There is little empirical work published on the impact of AI and the challenges it brings to innovation management to date. Contrasting with the great amount of investment in studies about the overall potential of AI technologies, not only published by academics but consulting firms as well (Prem, 2019).

In Scopus database, when using the research words “Artificial Intelligence and Innovation” there were available 37 publications, being the first one published in 2006.

In the same database, when the research words were “Artificial intelligence impact on innovation” there were no results available to date.

On google scholar, there were available 191 results regarding “Impact of Artificial intelligence on Innovation” on the last 5 years.

Though innovation is quite complex to achieve for every organization, studies show that organizations are looking towards IT as an enabler of process innovation (Anand et al., 2013).

Recently, researchers have shown some interest in the idea of AI and machine learning possibility of replacing humans and take over the workplace roles, changing the organizational structures and processes. The amount of literature on this subject has been growing steadily in the last years (Brynjolfsson & McAfee, 2017).

There is a reciprocal relationship between Big data and AI, as the latter depends on the former to succeed, while helping organizations to unlock the potential into their data sets. AI systems are able to help innovation managers to process much larger amounts of information than humans could possibly do on their own, adding that AI algorithms perform at a great speed, impacting the learning process momentum.

This fact is creating a phenomenon that Porter and Heppelmann (2017) describe as a disconnection between the huge amount of digital data available nowadays and the limitations of the physical world, in which information can be applied.

Some authors believe that the baseline for competitiveness of organizations lies on the information treatment and the problem-solving capacities.

If AI systems play a crucial role in collecting and analyzing data, then the way innovation is organized and its processes need to be challenged and adapted to the introduction of AI because those systems have important cost advantages in information processing (Haefner, 2021).

Artificial intelligence has not achieved a general intelligence yet, since most AI systems used nowadays display narrow intelligence in the sense that are extremely efficient in one or two tasks. Even though, they already excel largely human abilities in processing information in the area of idea development.

Current most advanced AI systems rely on deep neural networks that need and are able to process vast amounts of data at a great speed. Big data field plays a crucial role in the success of AI.

This way, in innovation processes’ stage of design thinking and implementation, AI can support managers in the development of ideas, and solutions. These developments are already creating significant value for companies (Roose, 2019 cited by Haefner et al., 2021).

To support the above affirmation with empiric evidence, there are some examples of AI applications. One of them is AI use to optimize battery components and solar cells by Machine learning based methods that are used to predict the most promising materials, speeding up the innovation process (Charington, 2018).

Another example is the business analytical tool application developed by Outlier (2020). The firm uses machine learning algorithms to process raw metrics data into information that humans can read. After analyzing the company’s data, Outlier generates a set of resumed customized

insights and “stories”. In doing so, these AI systems improve managers capacity to spot opportunities and come up with innovative ideas in many activities. This AI system is transversal to many sectors (Haefner, 2021; Outlier, 2020).

Artificial Intelligence is part of the technological revolution and influences all activities of a company’s value chain: Products and services; production processes; employment and human resources. Some authors agree that AI also has the potential to reshape how innovation processes and R&D are organized, having the potential to change innovation nature (OECD & Eurostat, 2018; Cockburn, Henderson & Stern, 2018; Haefner et al.,2021).

Cockburn, Henderson and Stern (2018) are a few of the researchers that have focused on the potential of recent developments in deep learning, to serve as a general-purpose method of invention (Agrawal et al., 2017).

Despite the lack of data on the subject of AI impact on innovation management, some authors have found some qualitative evidence about the repercussions of deep learning multi layered networks, in a range of tasks that include computer vision and other prediction tasks. AI expert on deep learning Geoffrey Hinton (2020) suggests that there were some great and rapid advances just in the last few years, on small algorithms related to multi-layered neural networks. These last developments on AI make some researchers believe that a new method of invention was created: machine learning. Despite in its early stages, the potential of machine learning and deep learning might create a new revolution, when focusing on organizational and policy consequences of AI. If there are increasing valuable outcomes in the scope of data acquisition that firms can obtain and use, it is possible that new and aggressive entrant companies in a particular sector might be able to create a significant competitive advantage over potential larger and older rivals. Merely because of control over data and not the usual formal intellectual property or demand network effects. This possibility can shift the way companies innovate. Even though, pressures and incentives to keep data private will weaken new entrants and researchers’ ability to study (Cockburn et al., 2018; Oliveira, 2017).

Algorithms should help managers make better decisions, generating a shift in which a large amount of data complex connections helps in the decision process. These mathematical models simplify work and have the ability to catalogue and organize information sets in a way that some models are more efficient than human decisions (Sousa & Rocha, 2019).

Machine learning as an invention of a method of inventing, might not only have an impact reducing costs of innovation activities, but it can generate a new approach and mindset towards innovation. A conceptual framework that integrates AI tools can lower-costs on research.

Within the research activities, some AI innovations improve access to knowledge and contribute to “lab productivity.”

Some authors stress that the economic impact of some research tools is not limited to reduce costs of specific innovation activities. From an organizational perspective, probably there will be significant changes towards research. Taking advantage of the combination of large datasets and deep learning algorithms, will create complex interdependencies also affecting interactions and communication among departments and workers. Changing the way organizations process information to a more inclusive and less centralized way, as workers who were not involved in the innovation processes in the past become part of it (Haefner, 2021).

Also, in the organization there is likely to be a shift from a more routinized labor-intensive research effort (testing hypothesis in small purpose-built datasets) towards research that takes advantage from large datasets and enhanced prediction algorithms.

In order to understand AI capabilities’ potential in assisting humans in the innovation process, it is important to understand some key technical features of those systems that are usually constrained by human capabilities: AI systems are created by humans who establish objective functions generally sparse, since human researchers who are programming the systems couldn’t know all the objectives of managers. The same happens for AI applications solution space, which are also pre-defined by humans thus, current AI systems tend to have a limited ability to explore the solution space autonomously (Haefner et al., 2020).

Also, some skills have not yet been acquired by machines such as creativity, imagination and critical thinking (Deng et al., 2020; Elish & Boyd, 2019). Thus, they have a supporting function but not taking over the entire innovation process for now, as it is improbable that whole series of connected tasks can be totally automated.

The lack of IT and AI experts is one of the biggest challenges for companies, as most firms' human capital lack those skills, even recent computer science graduates still do not possess enough expertise (European Commission, 2019).

Another barrier are the costs of creating the required know-how for innovations, as AI techniques

require many trial and error cycles during the development process.

The lack of technical predictability can be a challenge for innovation management, if expectations are high about AI possibilities. Experts warn about the danger of disappointment of modest performance of AI solutions. The disappointment might mean that companies delay too long to explore potential solutions (Penn, 2019; Haefner et al., 2020).

2 Conclusion

Despite its rapid evolution in the last years, AI is still in its initial stage.

In spite of the potential of AI and the increasing investment of companies, especially large ones, there is evidence that firms do not experience rapid beneficial outcomes, ending up blaming AI initiatives as a possible failure. AI systems are impacting product and process quality, decreasing de-routinization of jobs and allowing managers to be more focused on creativity and conceptually related tasks.

Artificial intelligence is being progressively included in companies' activities, but there are many challenges businesses face. authors stress that Artificial Intelligence systems need to be seen and adopted from the perspective of business capability as a general method of innovation. But for AI potential no be missed, companies will need to invest more on employees' skills and improve their capabilities of key employees like data scientists, who have statistical and big data skills.

For last and establishing the linkage between AI and Innovation Management European programs have put Artificial Intelligence on top of their agendas, with the European Commission (2018) encouraging countries and companies to step up investment in innovation and research on Artificial Intelligence.

Also, there are risks of losing out on the opportunities offered by AI which can have consequences for Europe, by becoming a consumer of solutions created elsewhere. Therefore, the EU should become a research powerhouse applying innovations in the market.

This work opens the path to more detailed research that will consider an empirical analysis of the application of these concepts in the entrepreneurial context.