XXIV SEMEAD
Seminários em Administração

novembro de 2021
ISSN 2177-3866

EXPLORING THE RADICAL INNOVATION FIELD: fundamental pillars and research agenda

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Agradecimento à orgão de fomento:
A pesquisa foi parcialmente financiada pela Fapesp – Fundação de Amparo à Pesquisa do Estado de São Paulo, processo 2015/26662-5

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Abstract
Radical innovation research has significantly impacted management research and is a driver for a firm's growth. Upon reviewing the literature, it became clear that the field of radical innovation is complex and disperse. So far, no study has surveyed the bibliography to identify the main terms and systematize the broad discussion of the radical innovation field. The research method is based on a systematic literature review, combined bibliometrics and content analysis. The sample consisted of 2.358 scientific articles and was quantitatively analyzed with the support of descriptive statistics and networks analysis. This study presents the emerging themes in the radical innovation field by analyzing the radical innovation area and mapping the main clusters present in the literature.

Keywords: *radical innovation, disruptive innovation, systematic literature review, bibliometric analysis.*

1. Introduction

Innovation is a widely recognized and discussed theme, both in academia and in industry. Discussions about its definitions, practices, types, degrees of intensity, and application contexts are essential for the conceptual and practical evolution of the field (Christensen, 2011; Garcia & Calantone, 2002; Griffin & Page, 1996; O'Connor, 2008).

In a dynamic economic environment where product innovation is essential to face competition, radical innovation might be the road to long-term business sustainability. Thereby, radical innovation research has been creating a significant impact on management research. In this paper, 'radical innovation' is described as innovations that face a high level of uncertainty in multiple dimensions (O'Connor et al., 2008). However, as some scholars have pointed out (Garcia & Calantone, 2002; O'Connor, 2008; O'Connor et al., 2008), there is no universal definition of radical innovation. As a result, many other terms refer to the same, or very similar, kind of innovation (e.g., breakthrough, major, strategic, disruptive). By the breadth of nomenclatures, the research landscape concerned with radical innovations has grown fragmented, leading to a research field that is difficult to overlook. According to Garcia & Calantone (2002), inconsistencies in theoretical and practical applications may arise when knowledge is not correctly defined. Over the years, different authors have proposed literature reviews on radical innovation. Despite the existence of these works, there is a gap in approaches that consider the entire spectrum of terminologies that represent the theoretical field of radical innovation.

Tiberius et al. (2020) present a literature review on radical innovation aiming to systematize the knowledge on the field and identify gaps for future research. Adopting the only term "disruptive innovation," the literature presents studies that explore the disruptive innovation process view (Petzold et al., 2019), a historical review of disruptive innovation (Shang et al., 2019), analysis of existing literature on disruptive innovation (Si & Chen, 2020), and the major researches on disruptive innovation (Martínez Vergara, 2022). Shang et al. (2019) article closely matches the purpose of this article. However, the work focuses only on the context of disruptive innovation. Additionally, the methodological approach is primarily bibliometric and describes the evolution of the theme over the years but does not synthesize the theme's literature. The absence of a more comprehensive analysis of the radical innovation literature is the main justification for the construction of this article.

The main evidence that the current literature reviews do not approach the radical innovation theme holistically is the strings used by authors. The articles that perform a broader search (Gomes et al., 2019; Sandberg & Aarikka-Stenroos, 2014) do not scan the literature as a research objective. Thus, the importance of developing a study that articulates the theme of radical innovation broadly is highlighted, grouping the different nomenclatures addressed by theory in radical innovation.

The present article is structured in five sessions. The subsequent section describes the methodology followed in carrying out the study. Section 3 presents the results obtained from the analyzes performed. In session 4 the discussion and directions for future research are presented, and in session 5 the conclusions.

2. Methodology

This study used the Web of Science (also referred to as WoS) main collection database in which 6468 articles were identified through the following topic search ("radical* innov*" OR "breakthrough innov*" OR "strateg* innov*" OR "major* innov*" OR "disrupt* innov*" OR "disconti* innov*" OR "explor* innov*"). Beyond the expression "radical innovation," it was chosen to include other terms as the keywords since the radical innovation phenomenon became widely known by these similar concepts with different nomenclatures (Bettencourt et al., 2007; Jansen et al., 2006; O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996; Zhou et al., 2005). Thus, through this approach, a broader view of the theme is covered.

Through a careful analysis of the WoS, Scopus, ProQuest, and Wiley databases indexes, a high degree of intersection of the journal across the databases are found. Therefore, the WoS was chosen as the main database for this research since it contains the leading journals in the areas of engineering and social sciences (Carvalho et al., 2013) and provides a set of metadata used in the bibliometric analysis (Gomes et al., 2019).

The results were refined by document type, and only "articles," "reviews," "book chapter," and "early access" types remained in the sample. Then, to focus on the subjects regarding the authors' research area, it was filtered by the following categories: "management," "business," "engineering industrial," "economics," "operations research management science," "multidisciplinary sciences," "engineering multidisciplinary," "business finance," and "engineering manufacturing domains", which resulted in a final sample of 2358 documents. No date filters were applied in this research, that is, all studies published as of January 2021 were considered in this literature review.

This research followed the workflow process described by Zupic & Čater (2015) for conducting science mapping with bibliometric methods. Through a comparative analysis of several bibliometric tools, the CiteSpace proved to deliver more resources for an extensive science mapping analysis. Therefore, the CiteSpace Software 5.6 was used to conduct the co-citation analysis at the document's level, followed by a cluster and burstiness analysis (Shang et al., 2019). The co-citation analysis and related network considered the Top 50 most cited documents of the dataset from 1974 (date of the oldest focal article) to 2020, one-year intervals sliced data.

The co-citation analysis connects documents, authors, or journals on the basis of joint appearances in reference lists. It also attributes a weight in accordance with the citation amount. In this case, citation is used as a measure of influence, because it offers a method to filter the most important works (Zupic & Čater, 2015). A co-citation is defined as the frequency in which two documents are cited together in the literature, documents are thus co-cited if they are included in the same reference list (Vogel & Güttel, 2013).

The software identified 12 major clusters presented in the network visualization (Figure 1). These clusters were analyzed through silhouette metric, which measures the consistency of the cluster's members. Following the cluster analysis, turning points and

emerging themes were explored through burst detection, aiming to identify uncommon elements across the literature (Figure 2). It allows for the identification of emergent publications regardless of how many times their host articles were cited. Therefore, relevant themes were methodically analyzed despite their popularity.

In order to justify the existence of this article, an analysis of the literature review articles on radical innovation was carried out. For the construction of the analysis, the Web of Science Core Collection database was used through the following search string ("radical * innov *" OR "breakthrough innov *" OR "Strateg * innov *" OR "major * innov *" OR "disrupt * innov" AND "systematic literature review" AND "bibliometric analysis"). The results were refined by only "articles reviews," resulting in a sample of 37 documents. The authors read the articles and only documents that were not in the research area or scope of the work were excluded. Thus, it resulted in a final sample of six documents that we are using as a justification.

The research of these articles identified that the keywords are very specific terms, which makes the reviews focused on only one aspect of radical innovation. Thus, the articles in this sample deal with the literature review in the field of disruptive innovation, mainly. No articles were found that dealt with the topic more broadly.

Thus, the importance of developing a research that addresses the theme of radical innovation in a broad way is highlighted, grouping the different nomenclatures that the theory addresses in radical innovation. It is also noteworthy that no article dealt in the literature review with historical, bibliometric and content aspects at the same time, so this article proposes to interconnect them in order to provide an overview of the theme.

3. Results

3.1. Co-citation Analysis

An analysis of the co-citation network was conducted, pursuing a deeper understanding of the intellectual roots of radical innovation (Figure 1). The cluster analysis provides a visual mapping of the co-citation network and labels the cluster based on a semantic analysis from the title, abstract, and keywords of the focal articles related to the cited references. The map presents the biggest twelve clusters. In the following paragraphs, the clusters are briefly described.

The main theme of cluster 00 is to understand how different aspects impact innovation performance. Forés & Camisón (2016) examine the effects of internal knowledge creation capability, absorptive capability, and size on incremental and radical innovation performance. Menguc et al. (2014) examine the relationship between customer and supplier and their involvement in the design process and new product performance. Norman & Verganti (2014) reframe the discussions of product innovation in the design and management context, analyzing the techniques used to support each type of innovation. Laursen & Salter (2014) explore how firms choice to be open to different external actors is related to their choices about their applicability strategy.

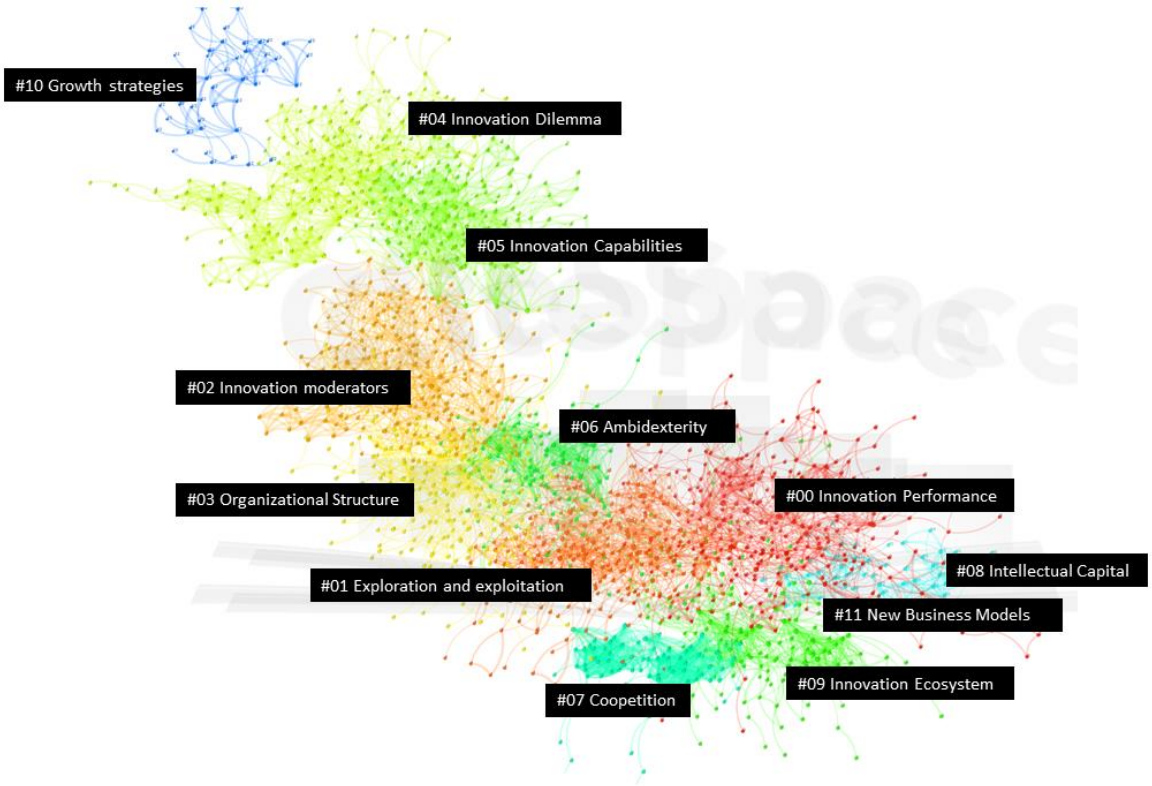

Figure 1. Cluster co-citation network

The articles gathered in cluster 01 address how companies deal with exploration and exploitation. Gupta et al. (2006) discuss some central issues related to exploration and exploitation concepts. Jansen et al. (2006) explore how formal and informal coordination mechanisms and the environmental aspects moderate the effectiveness of exploratory and exploitative innovation. Danneels (2004), Henderson (2006) and Markides (2006) challenges and integrates current theory in the domain of Christensen on disruptive technology and raises questions to initiate new works.

According to co-citation analysis, the main theme of cluster 02 is to understand the innovation moderators and how it impacts innovation performance. Zhou & Li (2012) indicate that a firm with a broad knowledge base is more capable of developing radical innovations in the presence of internal knowledge sharing rather than external-focused market knowledge acquisition. Slater et al. (2014) identified a set of organizational components related to a radical product innovation capability analyzing a complex interplay between and among them. Story et al. (2011) uses the lens of the network to foster the understanding of radical innovation capabilities.

Cluster 03 represents the discussions about how established organizations arrange themselves for radical innovation. For example, O'Connor (2008) draws on systems theory, dynamic capabilities theory, and the management of innovation literature to offer a framework for building a major innovation (MI) dynamic capability. The author suggests that dynamic capabilities for phenomena as complex as MI must be considered in a systems fashion rather than as operating routines and repeatable processes as the literature currently suggests. Kelley (2010) examines how established companies organize programs for fostering technology-based radical innovation.

Cluster 04 addresses the dilemma in the radical innovation process. Christensen (2011) presents that disruptive technologies bring to market a new value proposition in contrast

to sustaining technologies that incrementally improve established products' performance. Christensen also introduces the principles of Disruptive Innovation that guides managers on how to face the Innovator's Dilemma. Lynn et al. (1996) explore how companies develop an understanding of the markets for discontinuous innovations. O'Connor (1998) explores how the market-learning for radical innovations differs from incremental NPD projects, examining the nature and timing of market-related inquiry; market learning methods and processes; the scope of responsibility for market learning, and confidence in market learning the results.

The Cluster 05 explores the capabilities surrounding the radical innovation process. It analyzes the processes management activities and the effectiveness of the management practices for the results of radical innovation in the company. Benner & Tushman (2003) investigate the influence of dynamic capabilities, rooted in exploitation and exploration, in management activities for innovation and organizational adaptation. Hill & Rothaermel (2003) explore the performance factors caused by radical innovation in the market. Jansen et al. (2006) scrutinized the influence of environmental aspects in the effectiveness of exploitation and exploration, finding that an exploratory approach is more effective in dynamic environments, and exploitation is positively influenced by formalization and is more suited in competitive environments. McDermott & O'Connor (2002) analyzed radical new product development from a strategic perspective, finding three high-level strategic themes: market scope, competency management, and individual issues.

Cluster 06 develops discussions about organizational ambidexterity and the implementation mechanisms. Literature reviews on the subject are carried out to justify that the literature is not yet clear on the theoretical limits of ambidexterity (Ambrosini & Bowman, 2009; Raisch & Birkinshaw, 2008). The formal implementation of ambidexterity in the organizational structure is also discussed (Jansen et al., 2009). It is noticed that the theoretical discussion about ambidexterity is present in technological environments (Benner & Tushman, 2003; Eggers & Kaplan, 2008). Tensions about the organizational division in ambidexterity context are also discussed (Farjoun, 2017; Raisch et al., 2009).

Cluster 07 is about the debate on coopetition, the collaboration between competing companies (Ritala & Hurmelinna-Laukkanen, 2013), views issues of knowledge management and information sharing externally (Mention, 2011; Wu, 2014). In addition to discussing internal tensions (Raza-Ullah et al., 2014) and developing structural models for managing tensions (Fernandez et al., 2014). The cluster highlights the discussions about the tensions generated by the coopetition, as a collaboration between competing companies can cause benefits as harm to organizational performance, and managing collaboration is of paramount importance (le Roy & Czakon, 2016).

Cluster 08 discusses issues related to the intellectual capital of organizations as well as the leadership profiles in innovation management. Thus, we highlight the texts that carry out analysis of the leadership style to encourage innovation, focus on transactional and transformational styles (Berraies & Bchini, 2019; Havermans et al., 2015; Zuraik & Kelly, 2018) . Regarding the discussion of intellectual capital, the articles discuss the importance of human, social and intellectual aspects to develop innovations (Buenechea-Elberdin, 2017; Cuevas-Rodríguez et al., 2014; Dost et al., 2016).

Cluster 09 is divided into the discussion of innovation ecosystems and disruptive innovation. Such fields are evidence of established organizations and strategies for companies to remain competitive. Thus, some articles propose the structuring of the innovation ecosystem in the innovation ecosystem (Adner, 2017; Clarysse et al., 2014) and discuss the opportunities and challenges that the innovation ecosystem faces (Overholm, 2015). Also, protection of established organizations through regulatory frameworks (Gurses & Ozcan, 2015). Finally, the counterpoint in which established organizations are controlled by the market, but can also be

influenced by it (Sandström et al., 2014). The discussion about the innovation ecosystem highlights the importance of tools for environmental management.

Cluster 10 represents the discussion about the growth strategies of established organizations. The articles address topics such as strategic dissonance as an opportunity for organizational growth (Burgelman & Grove, 1996); corporate entrepreneurship from the perspective of creating competitive advantage with the development of new products in established organizations (Covin & Miles, 1999). In summary, the cluster presents the discussion of strategies for established organizations to innovate.

The main subject of cluster 11 introduces the new business models supported by radical and disruptive innovation (Pandit et al., 2018; Zeschky et al., 2014). Cluster 11 debates about innovation and low-cost technologies used by emerging economies. The debate is mainly located in eastern countries, such as India and China (Zeschky et al., 2014).

Summarizing, clusters present a macro perspective of the field of radical innovation. The main points focus on the established organizations seeking to remain competitive. Ambidexterity is the main subject debated among the clusters, followed by exploration, exploitation, and dynamic capabilities. Other clusters present discussions still emerging about the field. For example, frugal innovation and the innovation ecosystem. Such themes still seek their conceptual consolidation and forms of management.

3.2. Burst citation analysis

The citation burst helps to identify the evolution of the main themes of the literature (Figure 2). It provides a complementary analysis for a deeper understanding of the emergent themes and the ones that have already received great attention over the development of the field.

Through citation burst analysis, the most cited authors show that, over the years, literature on radical innovation has been expanding its domain to build a strong understanding of managing radical innovation systems, integrating several dimensions involved in such a complex. The first works that appear on the list show the concern to consolidate the theoretical and practical discussions that were being made about radical innovation. The work of Garcia & Calantone (2002) is a picture of this situation. The objective was to delimit the concepts better so that a common understanding of the phenomenon could support works, mainly case studies and that the practical results could be comparable.

The presence of two books on the list demonstrates the desire for greater diffusion of the theme to large established companies. Sorescu et al.'s (2003) work reinforces the importance and the advantages of these established companies in developing innovation, directing more efforts to carry out case studies in the area. The result of this effort to direct practice is evidenced by the presence of the text on Eisenhardt & Graebner's (2007) case study methodology, as one between the years 2008 and 2012.

Following concepts definition and due to the greater diffusion of the theme's importance to companies, the discussion of radical innovation becomes how to balance the company's radical innovation activities with those related to incremental innovation. The discussion of ambidexterity is represented in the figure by the synthesis presented by Raisch et al. (2009), Raisch & Birkinshaw (2008) and Cao et al. (2009). The organizational ambidexterity continues to be discussed over the years until it is consolidated again in O'Reilly & Tushman (2013) review, which remains with a strong citation burst until 2018.

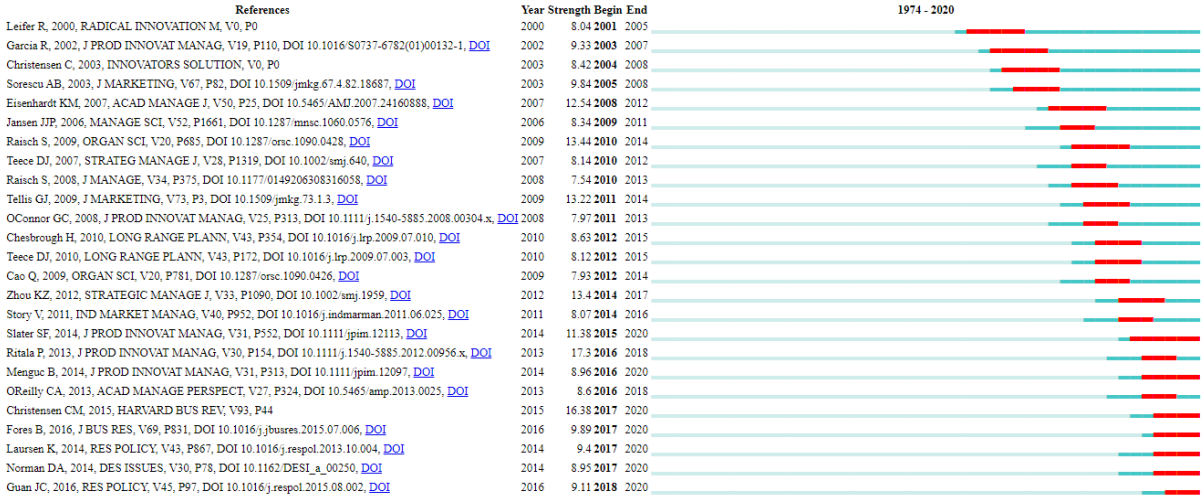

Figure 2. Top 25 references with the strongest citation bursts.

In parallel with the ambidexterity discussions, the articles discuss the company's capabilities for radical innovation. Slater et al. (2014) highlight elements that impact the company's ability to make radical innovation, such as the organizational culture, leadership, process, organization characteristics, and product launch strategy. Other authors emphasize that the construction of capacity stands out from the creation of a management system for radical innovation, interaction, and cooperation with customers and other actors in the innovation chain. O'Connor et al. (2008) advocate for the constitution of a dedicated organizational structure to develop and hold this capability to systematically generate innovations grounded in seven key elements. Menguc et al. (2014) examine the relationship between customer and supplier involvement in the design process and new product performance. Laursen & Salter (2014) explore how firms' choices to be open to different external actors are related to innovation capabilities. In addition to these factors, the literature on radical innovation has addressed knowledge management as one of the main ways of consolidating capacities for innovation. Zhou & Li (2012) examined the interaction of the existing knowledge base (breadth and depth) of the firm with knowledge integration mechanisms (internal knowledge sharing and market knowledge acquisition) for radical innovation. Ritala et al. (2013) found contingencies related to external collaboration and performance, looking at firm-specific factors: absorptive capacity and appropriability. Forés & Camisón (2016) examine the effects of internal knowledge creation capability, absorptive capability, and size on incremental and radical innovation performance.

Recently, a citation burst to papers that explicitly address the role of networks in building radical innovation capacities in companies. Story et al. (2011), also identified as an author with burst citation in recent years, uses the lens of the network to foster the understanding of radical innovation capabilities. Guan & Liu (2016) explore the structural properties of a knowledge network between companies and their possible influences on organizational innovations regarding exploitation and exploration in the emerging nano-energy field.

4. Discussion and directions for future research

A research framework on radical innovation was developed from the literature analysis, showing the main pillars of theoretical development in the field (Figure 3). The radical innovation literature can be analyzed from different perspectives, at the level of a project, process, management system, company, and ecosystem.

The vast bibliography has addressed the tensions that arise from the interaction and comparison between radical and incremental innovation (Cluster 01). For this reason, the literature analysis framework brings representations of radical and incremental innovation systems. Ambidexterity research (Cluster 06) seeks a way of balancing these two views. In both systems, moderating factors of the innovation development process and the impact of the differentiation of inputs (Cluster 08 and 10) that make up the system, such as organizational structure, individuals, management strategies, technologies, and knowledge, are studied. At the project level, the main topics covered are related to the characteristics of the developed project as well as the evaluation of its main results and effects for the organization (Cluster 04).

At the organizational level, the main themes are related to the company's capabilities for innovation (Cluster 05), which guarantee the proper functioning of the company's systems. The company's strategy for innovation (Cluster 03 and 11) are the guidelines for the company's internal efforts for innovation. Moreover, the strategy is the main external link between the company and the ecosystem of innovation (Cluster 09).

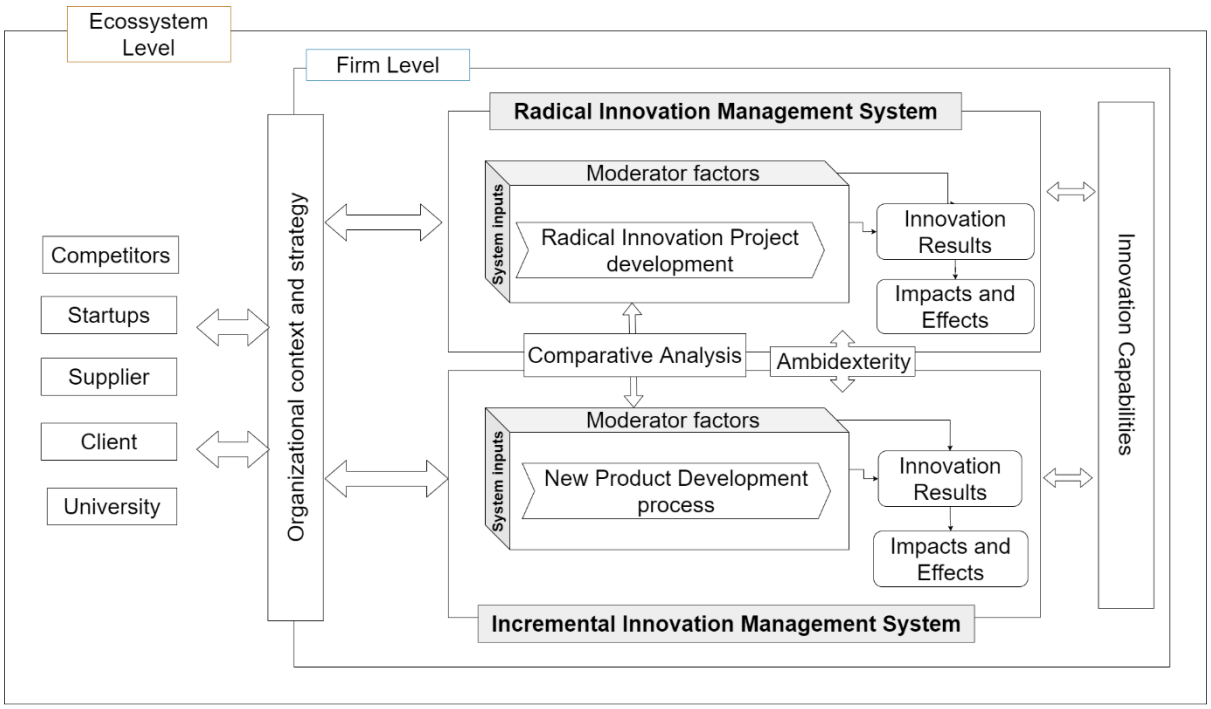

Figure 3. Radical innovation research framework

Our research framework considered the diversified nomenclature adopted in the field to understand how radical innovation is being studied, mapping opportunities for future study.

The data set analyzed showed an evolution in ecosystem studies in radical innovation, focusing on the relationship with external entities, such as startups, universities, and companies. Therefore, the theme of innovation ecosystem is considered emerging, from which recent studies seek to delimit the field (Adner, 2017; Gomes, Facin, et al., 2018) or analyze how to manage the ecosystem, mainly dealing with uncertainties (Gomes, Salerno, et al., 2018). Alliances and other open innovation mechanisms can be more explored in the future.

Recently, capabilities for radical innovation have been gaining attention, as demonstrated by the strongest citation burst analysis. Research related to innovation as dynamic capabilities is considered consolidated. However, sub-themes emerging from the field, such as the capacity for radical innovation focusing on managing the intellectual capacity

and knowledge, still require studies at the individual level (Dost et al., 2016). It is important to study how these capabilities for radical innovation are built by organizations.

A better understanding of how the creation of these capabilities is related to the company's networks is also a relevant topic for future research. The study of networks for radical innovation is not just about the relationship with the ecosystem. It is increasingly important to understand intra-organizational networks as alternatives for mobilizing resources to develop projects with greater uncertainty. A research agenda related to radical innovation projects that seek social and environmental improvements is a trend for future research, mainly due to the emergence in the literature of texts related to frugal innovation. Additionally, it is proposed to further studies the understanding of how new project contingencies impact on its development in terms of management, technological aspects, or company strategy.

5. Conclusion

This paper provides three contributions to literature. First, we answer the needs of a study that broadly articulates the theme of radical innovation, systematizing the knowledge and grouping the different nomenclatures that address the same theory of radical innovation. Second, we propose a wider discussion embracing these several terms that refer to radical innovation. Third, we provide directions for future research, presenting the emergent topics related to radical innovation.

Another contribution of this article is the data analysis method itself, which is structured and, thus, replicable to other themes. However, these methodological choices bring limitations to the research. Inclusion and exclusion criteria for articles limit the sample. The inherent subjectivity of analyzing and coding process by the researchers may have included unwanted bias in the analysis.

Radical innovation research has created a significant impact on management research and is a driver for a firm's growth. However, there is a gap in approaches that consider the entire spectrum of terminologies representing the theoretical field of radical innovation.

Finally, we suggest that the discussion between the relationships of the coded themes, particularly regarding the radical innovation, be explored in new studies in literature, considering innovation with a focus on the individual networks for innovation and the innovation ecosystem.

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