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INNOVATION CAPABILITY MATURITY IN NON-R&D PERFORMERS: A REFERENCE MODEL

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ABSTRACT

Highlights: The prevalence of Research and Development (R&D) as an inducing factor for innovation has been questioned, and studies show that low-tech companies are able to innovate. Innovation capability is essential to increase productivity and improve competitiveness. However, when formal R&D is considered as the main parameter in its evaluation, it tends to underestimate it. The extent and heterogeneity of studies on innovation in non-R&D practitioners is a relevant problem and, despite theoretical and empirical advances, it is not satisfactorily resolved yet.

Goal: This article presents a reference model for innovation capability maturity in low-technology, non-R&D performing companies, oriented to guide decision makers and the institutions supporting these organizations.

Design / Methodology / Approach: The method used to construct the model is based on the proposition of Ahlemann and Gastl (2007) for the construction of reference models based on empirical evidence.

Results: The model is based on ten organizational dimensions and their effects on the organization's performance. Five maturity levels are defined, synthesizing the fundamental characteristics of innovation capability in non-R&D practitioners or low technology companies.

Limitations of the investigation: Although the model has been tested and validated, more applications and tests may still be required.

Practical implications: The model is an important tool for decision-making, at the management level, in low-tech companies that aspire to broaden their innovation capability.

Originality / Value: The model has significant potential academic repercussions, in terms of the expansion of knowledge, as well as for the industry, since it can contribute to the increase of the competitive performance of companies.

Keywords: Innovation capability; Reference model; Low-tech; Informal R&D; Maturity.

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1. INTRODUCTION

A significant amount of literature regards economic growth and increased competitive advantage as fully explained through the endogenous activities of firms, more specifically by institutional R&D activities, which would be the main source of technological progress. The dissemination of this interpretation, adopted in studies on innovation over decades, thus generated a general understanding that there is a linear relationship between economic growth and technological progress (Hervas-Oliver *et al.*, 2011; J-Figueiredo *et al.*, 2017; Som, 2012). However, studies show that low-tech, non-R&D performing companies are able to innovate (Arundel *et al.*, 2008; Rammer *et al.*, 2009), and the prevalence of R&D as an inducing factor for innovation has been questioned particularly when the Resource Based View (VBR) is adopted (Barge-Gil *et al.*, 2011; Ortega-Argilés *et al.*, 2009; Rammer *et al.*, 2009; Santamaría *et al.*, 2009).

The VBR theory postulates that the innovation capability "is more likely to be based on firm-specific routines and firm-individual heuristics instead of merely single, homogeneous R&D-based innovation strategies" (Som *et al.*, 2010, p. 2). Thus, firms that do not invest in institutional R&D and are able to survive in their markets for long periods present a challenge to the idea that low R&D intensity is associated with stagnation and decline (Lopes *et al.*, 2016; Hirsch-Kreinsen, 2008; Kirner *et al.* 2009; Som, 2012). Francis and Bessant (2005, p. 171) argue that "enterprises that are better able to manage innovation than others and demonstrate a record of successfully exploiting new ideas can be said to possess, at least for a period of time, a superior 'innovation capability'". But when formal R&D is considered as the main parameter for evaluating the innovation capability of an enterprise, it tends to underestimate it, since informal and non-systematic R&D practices, such as 'learning by doing' and 'learning by using', for example, are neglected (Hervas-Oliver *et al.*, 2011).

In view of these arguments, this article adopts the premise that the extent and heterogeneity of studies on innovation in low-tech or non-R&D practitioners is a relevant problem, and despite the theoretical and empirical advances, it is not yet satisfactorily resolved (Raghuvanshi *et al.*, 2019), especially in terms of scope, completeness and reproducibility. Thus, the general objective of this article is to present the development – including the construction, validation and evaluation – of a reference model for innovation capability maturity in low-technology non-R&D performing companies, oriented to guide decision makers and institutions that support these organizations. In the context of this objective, the 'model' can be understood as "a set of propositions or statements which expresses relationships among constructs" (Bullinger, 2008, p. 221), while the term 'reference' refers to a normative or descriptive character (Winter and Schelp, 2006).

The article is structured as follows: in the next item, a theoretical background regarding innovation capability is systematized and discussed. The third item presents the method used to construct the model, which is an adaptation of the proposition of Ahlemann and Gastl (2007) for the construction of reference models based on empirical evidence. The fourth item presents and discusses the results, emphasizing the ontological aspects and the description of the five maturity levels of innovation capability in non-R&D companies. The validation and evaluation of the proposed model are also discussed in this item. Finally, the final item presents the conclusions, emphasizing conceptual and practical implications and limitations.

2. THEORETICAL BACKGROUND

Lawson and Samson (2001) argue that innovation capability is a conceptual framework that aims to describe actions that can be taken to improve the success of innovation activities and efforts. Complementarily, Metz *et al.* (2007) argue that innovation capability is perceived as a complex concept because it is influenced by internal and external factors. This implies a fundamentally intangible nature for this construct, making its study complex and diffuse. Expanding this conceptual perspective, Saunila and Ukko (2012) affirm that the concept of innovation capability includes three elements: innovation potential, innovation processes, and the results of innovation activities.

Narcizo *et al.* (2017) identified 19 definitions for the construct of 'innovation capability'. According to these authors, the theoretical domain related to this construct is implicitly structured in a typology of artifacts that present characteristics analogous to the predicted uses of maturity models. Thus, there are three main classes of models for innovation capability: (1) descriptive, (2) comparative, and (3) prescriptive. Descriptive models are focused on what is innovation capability and are divided into the subclasses of 'definitions' and 'organizational dimensions and (or) results'. Comparative models aim to represent the dynamics of innovation capability in an organization, divided into 'conceptual models' and 'assessment instruments'. Finally, prescriptive models aim to represent innovation capability using reference or maturity structures.

Crossan and Apaydin (2010) argue that innovation capability lies in 'managerial mechanisms' that enable innovation. Complementarily, Saunila *et al.* (2012, p. 418) argue that, because innovation capability is essentially intangible, it cannot be measured directly, but only from the organizational foundations that sustain it. These foundations act for innovation efforts as drivers (when employed positively) or as obstacles (when employed negatively), unfolding themselves in tangible aspects, such as inputs, human and finan-

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cial resources, and equipment and physical infrastructure; or intangible, such as leadership, managerial practices and processes, motivation, knowledge, culture, and other organizational dimensions. Narcizo *et al.* (2013), based on the works of Koc (2007), Laforet and Tann (2006), Perdomo-Ortiz *et al.* (2006), Wang *et al.* (2008), Yam *et al.* (2011), among others, propose a set of ten different dimensions linked to the foundations of innovation capability. Although these organizational dimensions can be explained in different ways, they are commonly presented as learning, culture, strategy, structure, leadership, marketing, processes, people, resources, and external linkages (or relationships with the external environment).

In terms of contributions on the understanding of innovation capability, Lawson and Samson's (2001) conceptual model stands out when adopting a holistic view on this construct, avoiding representing the innovation management process as a 'blackbox'. Crossan and Apaydin's (2010) model has contributed to the literature by offering a multidimensional and comprehensive conceptual framework on innovation, on which it is possible to construct measures on innovation capability and its results in terms of their dimensions and determinants.

When an organization seeks to develop its innovation capability, innovative outputs are expected. Thus, similarly to the idea of organizational foundations (in terms of inputs and dimensions), the literature also presents a set of results (in terms of outputs and effects) deriving from the development of innovation capability. According to the Oslo Manual (OECD, 2005), four types of innovations can be distinguished: product innovations, process innovations, marketing innovations and organizational innovations. The effects of innovation capability development can also be understood and measured from different organizational performance perspectives, as in these examples: increased competitiveness, turnover or profitability (Neely *et al.*, 2005).

Hudson *et al.* (2001) propose an innovation capability effects evaluation model based on two fundamental perspectives: financial and non-financial. Complementarily, Stock and Zacharias (2011) propose a model that includes the degree of novelty, the value generated and the frequency of innovative outputs. In the same direction, Saunila and Ukko (2012) suggest an evaluation of the effects on organizational performance in terms of efficiency and effectiveness, considering operational, customer satisfaction, human and financial resources perspectives. Integrating convergent views on this subject, Narcizo *et al.* (2018) suggest a framework that synthesizes the approaches presented by Edwards *et al.* (2005), Hervas-Oliver *et al.* (2015), Hudson *et al.* (2001), Keskin (2006), Laforet (2011), Ngo and O'Cass (2012), OECD (2005), Saunila and Ukko (2012), Simpson *et al.* (2006) and Stock and Zacharias (2011) on performance perspectives, performance factors, and evaluation parameters of innovation capability.

By using constructs related to the organizational foundations and results of innovation capability, the reference literature presents a plethora of conceptual models that seek to represent innovation capability in organizations, such as found on Crossan and Apaydin (2010) and Lawson and Samson (2001). In addition, there are models oriented to the measurement, evaluation or comparison of innovation capability between organizations, such as in Martínez-Román *et al.* (2011) and Saunila and Ukko (2012). Martínez-Román *et al.* (2011) propose a conceptual model based on innovation capability, which includes the explanatory variables and contextual factors of companies - both internal and external - such as environment characteristics, innovation capability dimensions and innovative outputs. Saunila and Ukko (2012) suggest an evaluation model with an emphasis on the relationship between innovation capability and organizational performance. For this, they establish a definition for the construct and a conceptual framework to support its evaluation, encompassing the potential, processes and results of innovation.

There are also references or maturity models for innovation capability, although they are relatively recent in the literature. Röglinger *et al.* (2012, p. 4) state that maturity models "typically represent theories about how an organization's capabilities evolve in a stage-by-stage manner along an anticipated, desired, or logical path". According to Mettler *et al.* (2010, p. 334) the term 'maturity' "implies an evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target from an initial to a desired or normally occurring end stage. The purpose of maturity models is to guide through this evolutionary process by incorporating formality into the improvement activities". By stressing the potential character of innovation capability, as proposed by Neely *et al.* (2000) and Saunila and Ukko (2014), it is possible to establish a connection between this organizational property and the logic of maturity levels. In terms of organizational processes, maturity models increase as the organization meets certain requirements and reaches a certain degree of evolution in its business processes.

The Capability Maturity Model Integration (CMMI) is a maturity model that defines best practices that help organizations improve their processes (Chrissis *et al.*, 2011). It is based on the proposition of five levels of maturity, defined by special requirements that are cumulative, as well as process capabilities that are expected for each level (Röglinger *et al.*, 2012). In terms of relevance to innovation capability, the reference model proposed by Francis (2000) and the maturity models of Bessant (2003), Corsi and Neau (2015) and Essmann (2009) should be highlighted. These last three models start from a similar premise, that "an innovative sit-

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uation is not a binary one, and there is no one-size-fits-all innovation process maturity level" (Corsi and Neau, 2015, p.5), suggesting that there are five evolutionary levels for innovation capability's maturity.

Francis (2000) developed a reference model to help organizations assess the extent to which they were practicing behaviors associated with high innovation capability. The model does not present a maturity structure; instead, it is based on six core domains: direction, which encompasses aspects related to strategy, leadership and boldness; capability, encompassing people and organizational resources; culture in terms of empowerment and engagement; learning, including connections with the external environment; structure and processes, with particular emphasis on R&D; and decision making, covering aspects related to commitment. In turn, Bessant (2003) suggests a model based on the premise that continuous learning is a dynamic capability of organizations. With five evolutionary levels, it can be understood as a systemic process focused on sustaining incremental innovations, since it offers mechanisms through which the organization can become more involved with innovation and learning processes.

Constructed based on the CMMI, the model proposed by Essmann (2009) aims to identify the organizational components of innovation capability. It is basically composed of a conceptual framework, which supports its structure; a set of fundamental requirements that assist in assessment and measurement; and a set of organizational roles, related to the positions and actions of individuals in relation to innovation in the organization. Finally, the maturity model proposed by Corsi et Neau (2015) also contains five levels. Its main objective is to trace the potential of innovation in each of these levels and to describe the specificities of process that indicate a greater or lesser innovation capability. The first four levels of the model derive from a set of principles that apply to the operationalization of innovation in the organization, starting from (1) doing well; to (2) repeating better; going on to (3) coordinating together; and then (4) managing consistently. Thus, each level of maturity is focused on developing unique and indispensable skills for further progress. Finally, 'sustaining', the fifth and last level of maturity, integrates all previous progress, preventing the company from going through all the previous stages in each new initiative, promoting sustainability in innovation.

Analyzing the models mentioned, it is possible to verify that Francis (2000) offers a model deduced from empirical evidence, based on a broad literature review and a robust conceptual base of reference. However, it does not predict maturity levels. In addition, it was built using data from high-tech companies or R&D practitioners. Bessant's (2003) model stands out for distinguishing and emphasizing the people's involvement as a determining factor for the success of innovations, suggesting that maturity levels derive from a combination of management practices and performance. Essmann (2009) clearly defines three levels of maturity for each parameter of the model, which is designed and formatted pragmatically as an instrument of organizational intervention. However, it can be excessively complex due to the inclusion of the organizational role dimension, so that innovation capability maturity becomes dependent on a combination of multiple dimensions. Finally, Corsi and Neau (2015) propose a flexible and adaptable model for different use cases, even in small or low technology companies, but offer a limited discussion about the model construction and validation process.

3. METHOD

Innovation research using Design Science produces descriptive or prescriptive artifacts. Descriptive artifacts are used to represent statements about the object of analysis, where their most important quality is an adequate representation of the 'truth'. Prescriptive artifacts, however, are related to some purpose or objective, so their most important quality is utility or 'value in context and use'. There is a hierarchical typology for these artifacts in Design Theory, which can be structured in terms of constructs (ontological facts), models (theoretical statements), methods (algorithms or practices) and instantiations (physical realizations) (Winter and Aier, 2016).

The reference model presented in this article was developed using an adaptation of a method for the construction of reference models based on empirical evidence (Ahlemann and Gastl, 2007). The method is based on a constructivist epistemology, so that the propositions contained in the reference model were examined by experts regarding their acceptance and validity. In addition, this method was made compatible with the guidelines of Bruin *et al.* (2005) on the general attributes and processes of design and use of maturity models.

Throughout the development of the model the orientations of Mettler *et al.* (2010) on the distinctive features of maturity models have been respected and integrated into the design process. These characteristics included: general attributes (basic properties), design principles (construction, organization and structure); and the principles of use (deployment, application method and support tools). Figure 1 illustrates the main phases of the model development method.

According to Ahlemann and Gastl (2007), while the first two phases of the method are oriented to the configuration and construction of the reference model, the following

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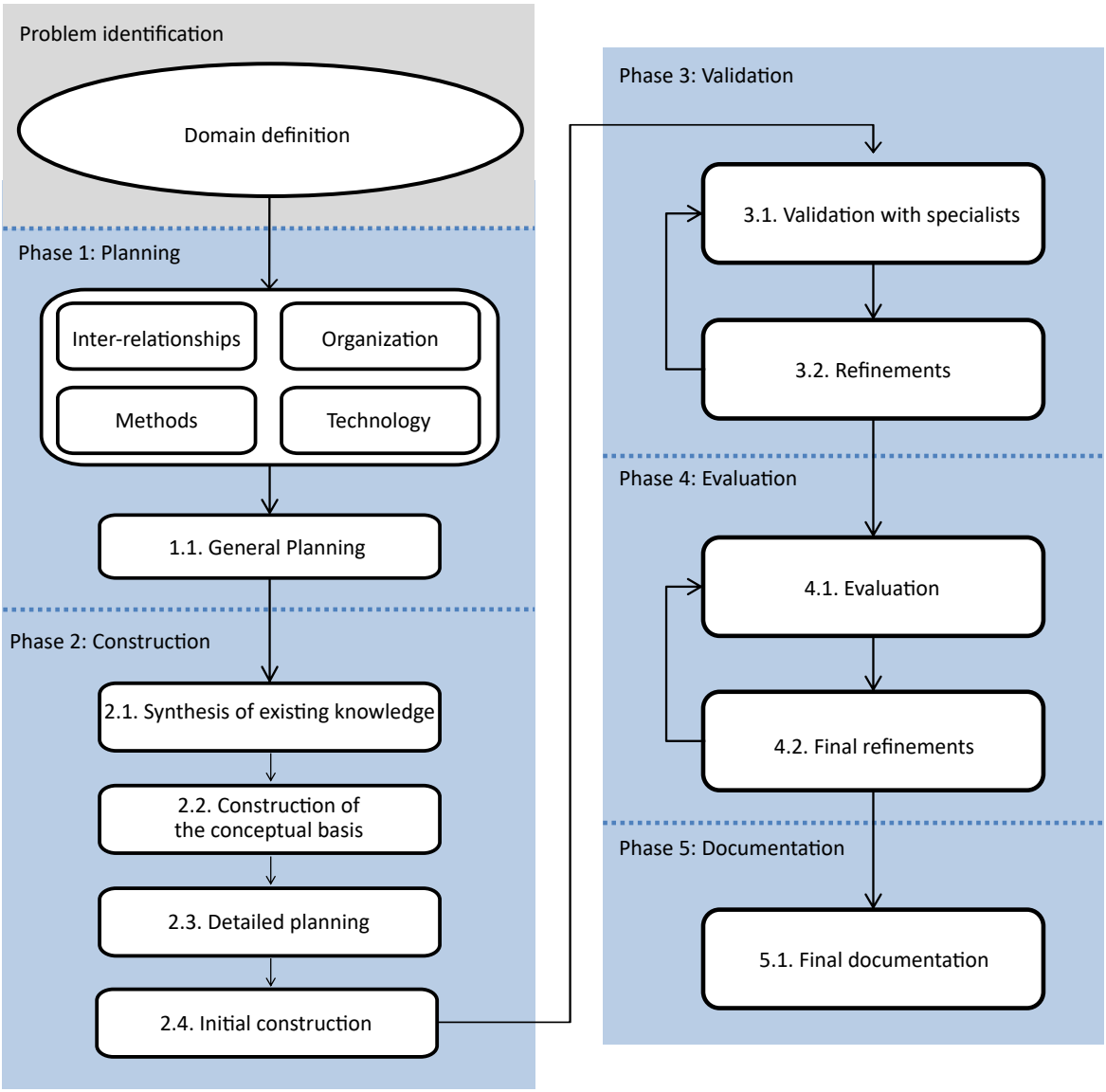

Figure 1. Main development phases of the reference model
Source: Adapted from Ahlemann and Gastl (2007, p. 82)

phases are aimed at stabilizing and refining it. Although the steps illustrated in Figure 1 are presented linearly, they were performed in iterative processes, where one or more cycles were required for a satisfactory result to be obtained at the end of a given phase. In summary, these phases encompassed the following activities:

- **Phase 0 – Problem identification**: In this phase the domain of the reference model was defined. The development of the model started from a clear and precise definition of the problem for which the model is oriented, that is, its theoretical and practical domain. This phase was carried out through workshops with subject experts from the Academy and from industry, where the definition of the domain was the result of a consensus of these experts in terms of acceptance of the validity of the definition of the problem, and of the fact that the development of a reference model would be a promising means to solve this problem.

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- **Phase 1 - Planning**: In this phase the object of the reference model, the methods that would be used for its construction, the way to organize the project and the software tools would be necessary for the use of the model were defined. This phase involved an analysis of the possible interrelationships of the model with other references, current standards and norms, an analysis of the methods employed, and how they would affect the temporal and logical sequence of the activities of model construction, organization and coordination of construction activities and an analysis of technologies to support the construction process. At the end of this phase, an initial planning of the model was created, in terms of the approach that would be used for its construction and the model's granularity structure, i.e. its various levels of abstraction and detail (Fox *et al.*, 2002). The construction was based on three stages. The completion of each stage added a greater level of detail and complexity to the model.

- **Phase 2 - Construction**: This phase involved the elaboration of a synthesis of existing knowledge on the theoretical domain, the construction of a conceptual reference base, the definition of the detailed planning of the construction, including all its elements and levels of granularity, and, finally, the construction of the first version of the model. For this, it was necessary to define the requirements for each level of maturity, associated with organizational dimensions and performance perspectives. Each level of maturity of the models presented in Item 2 (Theoretical Background) was mapped, identifying the main requirements proposed by the authors. Some of these requirements have been adjusted or adapted, guaranteeing alignment and conceptual compatibility among the propositions of the authors. Next, a redundancy and conceptual overload analysis was performed, eliminating incompatible or repeated requirements. The second step was to define the performance perspectives associated with the results, also based on the Theoretical Background. These were adjusted, guaranteeing alignment and conceptual compatibility. Next, a redundancy and conceptual overload analysis was also performed, eliminating incompatible or redundant requirements.

- **Phase 3 - Validation**: The objective of this phase was to ensure, from the adjustments and refinements derived from the interactions with the specialists, the adherence and adequacy of use of the model for the domain to which it is oriented. The validation was fundamentally aimed at ensuring a consensus among experts and developers. For this, there were cycles of iterations where new structures, entities and components were presented, debated and validated (or rejected). This logic implied that the validation occurred in a parallel and complementary way to the construction.

- **Phase 4 - Evaluation**: This phase involved pilot testing and evaluation of the reference model quality. The practical tests aimed to evaluate the degree of adherence to the problem, as well as its applicability by the users to which it is oriented. The approach used for the evaluation was based on multiple perspectives, as defined by Frank (2007), encompassing economic, application, engineering and epistemological aspects from the point of view of users of the model.

Table 1. Innovation capability components and references

COMPONENT	REFERENCES	
	Primary	**Secondary**
Construct definition	Neely *et al.* (2005); Saunila and Ukko (2012); Narcizo (2012).	Francis (2005); Guan and Ma (2003); Lawson and Samson (2001).
Inputs and organizational dimensions	Narcizo (2012); Narcizo (2017); Narcizo *et al.* (2017).	Branzei and Vertinsky (2006); Perdomo-Ortiz et al. (2006); Capaldo *et al.* (2003); Koc (2007); Laforet and Tann (2006); Nassimbeni (2001); Wang *et al.* (2008); Yam *et al.* (2011).
Outputs and performance perspectives	Hudson *et al.* (2001); OECD (2005); Saunila and Ukko (2012).	Edwards *et al.* (2005); Hervas-Oliver *et al.* (2015); Keskin (2006); Laforet (2011); Ngo and O'Cas (2012); Simpson *et al.* (2006); Stock and Zacharias (2011).
Organizational dimensions' requirements	Bessant (2003); Corsi and Neau (2015); Essmann (2009).	
Performance perspectives' requirements	Narcizo *et al.* (2018).	Ingley *et al.* (2017); Kazanjian (1988); Moy and Luk (2003); Scott and Bruce (1987).
Maturity structure	Chrissis *et al.* (2011); Corsi and Neau (2015); Essmann (2009).	

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Table 2. Ontological structure for innovation capability

DEFINITIONS	
Innovation capability is the potential for the development of innovations resulting from the synergetic interaction between a set of organizational dimensions that sustain, through management processes and practices, the transformation of knowledge and ideas into new initiatives for value creation that provides benefits to the company and its stakeholders.	
Organizational foundations of innovation capability are the inputs and organizational dimensions that, by interacting through managerial practices and mechanisms, enable and support the innovation efforts of an organization.	Organizational results of innovation capability are the innovative outputs and performance parameters, expressed in terms of internal and external efficiency and effectiveness, arising from an organization's innovation efforts.
ELEMENTS	
Inputs: Data and information on the market and technology, new knowledge, opportunities and ideas.	Outputs: Product innovation, process innovation, marketing innovation or organizational innovation.
Organizational dimensions: Learning; Culture; Strategy; Structure; Leadership; Marketing; Processes; People; Resources; and Relationships.	Performance perspectives: Operational; Customer satisfaction; Human Resources; and Financial.

- **Phase 5 - Documentation**: This phase encompassed the final registration of the model for its practical use. The final classification of the reference model was done using the guidelines of Fettke *et al.* (2006).

4. RESULTS AND DISCUSSION

To begin the model's development, a definition was proposed for 'innovation capability', where the definition of Narcizo (2012) was made compatible with the propositions of Neely *et al.* (2005) and Saunila and Ukko (2012). From the establishment of a definition for the most important construct in this domain, the second step in the process of constructing the conceptual framework of the model encompassed the definition of the foundations and the organizational results of innovation capability. The other components and their source references can be identified in Table 1.

The study of the literature presented in Table 1, coupled with the experience of specialists consulted during the model construction, led to the formalization of ten organizational dimensions that support innovation capability: learning, culture, strategy, structure, leadership, marketing, processes, people, resources, and relationships (or external linkages). Similarly, the organizational results of innovation capability represent innovative outputs, expressed in terms of product, process, organizational and marketing innovations, and their effects on the organization's performance: operational, customer satisfaction, human resources, and financial. Table 2 presents the main definitions and fundamental elements in the theoretical domain of innovation capability.

Then the textual descriptions were constructed for each of the five levels of maturity, encompassing the foundations and the results of innovation capability. These textual descriptions aimed to present a synthesis of the fundamental characteristics of each level of maturity for the innovation capability in non-R&D practitioners or low technology companies, presented as follows.

- **Innovation Capability Maturity - Level 1 - 'revealed innovation'**: At this level, the company identified and attended a market opportunity. It strives, from restricted or limited distribution channels, to keep its revenue from its main products. There are scarce resources; therefore, in financial terms, the focus is to obtain those needed to maintain the most profitable products. The company is basically oriented to its internal environment and its daily operations, paying little attention to prospecting partners or to constructing cooperation networks. Innovation is not a priority, but the interest in the topic may have been sparked by a crisis, a customer or supplier visit, or a seminar. This level is called 'revealed innovation' because innovation comes to be 'revealed' as 'salvation' to the long-term survival of the company, although management does not know how to achieve it objectively. There are eventual efforts to develop new solutions for customers; however, these initiatives - which are not always understood as innovation efforts - tend to be individual actions, without management support or encouragement, usually leading to the abandonment of the project. People and teams are limited in terms of training, skills and competences. When innovation projects are executed, they are based only on past analysis, and their implementation is *ad hoc*, without institutional support, infrastructure, systems, resources and tools, extrapolating deadlines and costs and making it difficult to be completed. The most relevant organizational dimensions for this level are 'Marketing' and 'Resources', and the performance perspectives are 'Customer satisfaction' and 'Financial' because they enable the birth and survival of the company by

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maintaining its main offers directed to the market.

- **Innovation Capability Maturity - Level 2 - 'experienced innovation'**: At this level, the company has already developed, at least, one successful innovation effort and is seeking to produce others. This is why the name 'experienced innovation', as the company has already experienced some benefit from innovation. Management now has a greater understanding of the key factors influencing innovation, which has become a necessity and is more aligned with the strategy. Although there is a limited line of products, the company explores and develops its main market. Incremental improvements in the main product and an increase in the operational reliability of the process are obtained, focusing on customer loyalty and the company's legitimacy in the market. There is greater predictability of revenues, so that the key resources for basic operations are secured, possibly complemented by capital injections or growth-oriented external investments. Initiatives or mechanisms for the collection and analysis of ideas are in operation, linked to a system of rewards. A significant number of people already participate and are trained in innovative practices. The company reuses practices, methods, tools, and problem-solving processes that have worked in the past, yielding good results. It has achieved good market positions for its products, but the innovative outputs are still inconsistent. The main organizational dimensions for this level are 'Learning', 'Structure', 'Marketing', 'People' and 'Processes', and the performance perspectives are 'Operational' and 'Customer satisfaction', suggesting the emergence of practices and organizational processes oriented to innovation. Thus, people can assume greater roles and autonomy in the processes, guided by cycles of learning in relation to the past, and focused on customer satisfaction and on the improvement of operational performance.

- **Innovation Capability Maturity - Level 3 - 'achieved innovation'**: At this level the company identified innovation as an organizational function, with goals formally deployed from the strategy. There is an institutional policy oriented to the stimulation and coordination of innovation, aligned with the availability of resources. Management disseminates and reinforces a shared vision of the importance of innovation for the company. Processes, departments and activities are understood and managed in an integrated and holistic way. Innovation activities are prioritized, receiving the resources needed to meet their goals and objectives, and are supported by an efficient infrastructure in terms of systems, tools and communication channels. Innovation teams are made up of people with diverse and complementary skills. The company has a portfolio of innovation projects, which are interdependent and coordinated in an integrated manner, sharing information on problems and solutions, where resources are allocated to the portfolio based on project prioritization. That is why this level of maturity is called 'achieved innovation', as the company has converted innovation into a continuous and managed process. The company encourages and facilitates the relationship and collaboration with external agents. There are innovation leaders who support and guide people through change initiatives. People are trained in tools, practices and methods for innovation, with a focus on knowledge capitalization. Periodical initiatives to probe the market are carried out, supported by institutionalized marketing procedures with clearly defined outputs. Production capacity has been expanded and improved, as well as sales capacity, through the diversification of distribution channels. Therefore, one or more high performance products are offered to the market. The customer base was diversified and there were increased orders in the portfolio. Revenues have become more predictable and profit margins stabilized, establishing the company's competitive position in the market. The organizational dimensions most relevant to this level are 'Structure', 'Leadership', 'Marketing', 'People', 'Processes', and 'Relationships', and the performance perspectives are 'Operational' and 'Customer satisfaction', which together reflect an organization based on a holistic perception about itself, oriented both to its internal and external environments.

- **Innovation Capability Maturity - Level 4 - 'improved innovation'**: At this level, the company is characterized by innovation, as it has become its driving force. Management began to monitor it closely, establishing a relationship between the business' requirements and the company's own model of innovation. There is an innovation policy implemented by a cross-functional committee, and innovation managers lead the way. The company is able to create internal sources for innovation, which are designed with a purpose and the desired attributes, becoming the link between projects, actors and markets. Culture encourages synergy between sectors and departments, and cooperation is systemic. There is an increase in the number of employees, but all are responsible for innovation and continuous improvement in the organization. People have the autonomy and empowerment to manage their own processes, integrating practices, procedures

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and tools, and there is freedom to experiment and seek new solutions. A multidisciplinary innovation management process is established, of which innovative outputs are consistent, diverse and a source of differentiation. New products are frequently developed and there is significant increase in sales volume and profitability. Market share is also positively impacted as a result of entering new markets and exploring other niches. That is why the name of the level is 'improved innovation'. The production and distribution processes are improved, generating an increase in production volume and achieving economies of scale. The financial independence of the company is strengthened and there is an increase in its legitimacy vis-à-vis the market, its customers and competitors. The main organizational dimensions for this level are 'Strategy', 'Structure' and 'Leadership', and the performance perspectives are 'Operational', 'Customer satisfaction', 'Human Resources' and 'Financial', showing that innovation is now formally managed, integrating and directing the company's strategy.

- **Innovation Capability Maturity - Level 5 - 'mature innovation'**: At this level, innovation has become a strategic priority for the company. Innovation and business strategies are synchronized with activities and innovation feeds itself into a positive loop as a result of learning throughout the organizational life cycle. There is a strategy of intellectual property protection and a systemic behavior, widely distributed, oriented to learning, so that the company approaches the model of the 'learning organization'. The company is able to get the right information at the right time and solve problems and obtaining and sharing knowledge is systematic. The nature of interaction with external agents is open and trustworthy, supported by institutional practices. The company is an element in co-evolution with an ecosystem of innovation, playing an active and influential role in the supply chain of this ecosystem. There are dedicated infrastructures, systems and tools to support innovation activities, with modularity and multifunctionality. Innovation is integrated with all other functions. Investments and structure provide sufficient 'gaps' and freedoms for activities to deviate from the standard, when necessary. Innovation practices, procedures and tools are institutionalized. Processes and projects are efficient, both globally and individually. There is management of knowledge, expertise, risks and competencies. The innovation model of the company itself is a product subject to continuous improvement. People have high levels of autonomy to experiment and innovate, actively participating in the innovation process. Teams have become a central aspect of the company, involving a multidisciplinary competency base beyond functional and organizational boundaries. Leaders support, coordinate, and ensure alignment among individuals' activities. Initiatives to probe the market occur regularly, with their results effectively employed to develop strategies for current projects and future planning. New lines and product families as well as second and third generation products are developed. Innovative outputs provide sustained competitive advantage in existing and new markets. New geographical territories are accessed; there is business diversification and consolidation of the market position, ensuring financial resources for growth. Financial performance is strengthened, and profit margins are optimized. The most important organizational dimensions for this level of maturity are 'Structure', 'Leadership', 'Marketing', 'Processes', 'People' and 'Relationships', and the performance perspectives are 'Operational' and 'Customer satisfaction', which suggests the importance of involving management, processes and relationships with the external environment, and highlighting the challenges and complexity of achieving such a level of maturity for innovation capability.

5. DISCUSSION

The model presents important characteristics regarding its construction and results. During construction, it was necessary to match the requirements of each organizational dimension and performance perspective considering characteristics of completeness, overload and excess. Two major difficulties were faced. The first involved the compatibility of management practices associated with organizational dimensions in a context that adheres to those of low-tech companies or non-R&D practitioners. This involved an analysis of the degree of requirement and complexity of each proposition, and later standardization of these characteristics.

As for validation and refinements, the combination of academic and market expertise was fundamental to the proposition of a cohesive and coherent model. The most relevant adjustment in the conceptual framework was related to the results of innovation capability. The model initially did not distinguish between outputs and effects, treating them in combination. The distinction between outputs and results was relevant for determining the type of innovation generated by the company (product, process, marketing or organizational innovation) and its effects, considering the prospects of operations, customer satisfaction, and human and financial resources. Table 3 presents the final classification of the model according to Fettke *et al.* (2006).

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Table 3. Classification of the reference model

Identification: Reference model for innovation capability maturity in low-tech companies or non-R&D practitioners.	
DESCRIPTION	
Origin	Academy and Industry.
Responsibility	The authors.
Access	Public, free and unrestricted.
Main theoretical sources and references	Bessant (2003); Branzei and Vertinsky (2006); Capaldo et al. (2003); Chrissis et al. (2011); Corsi and Neau (2015); Edwards et al. (2005); Essmann (2009); Francis (2005); Guan and Ma (2003); Hervas-Oliver et al. (2015); Hudson et al. (2001); Ingley et al. (2016); Kazanjian (1988); Keskin (2006); Koc (2007); Laforet (2011); Laforet and Tann (2006); Lawson and Samson (2001); Moy and Luk (2003); Narcizo (2012); Narcizo (2017); Narcizo et al. (2017); Narcizo et al. (2018); Nassimbeni (2001); Neely et al. (2005); Ngo and O'Cas (2012); OECD (2005); Perdomo-Ortiz et al. (2006); Saunila and Ukko (2012); Scott and Bruce (1987); Simpson et al. (2006); Stock and Zacharias (2011); Wang et al. (2008); Yam et al. (2011).
Target audience	Primary: Owners, managers or directors of low-tech companies or non-R&D practitioners. Secondary: Institutions to support and foster the development and growth of low-tech enterprises.
Support tools	None available at the moment, with the expectation of developing medium-term application tools.
CONSTRUCTION	
Domain	By object: Innovation Capability Maturity. By type of company: low-tech companies or non-R&D practitioners.
Modeling language	No specific language, using conceptual maps to support the construction process.
Modeling framework	Three levels of granularity for innovation capability: (1) ontological, presenting its main entities and components, (2) relational, including its foundations (inputs and organizational dimensions) and results (outputs and performance perspectives), and (3) prescriptive, defining the requirements for each of the five maturity levels.
Construction method	Based on empirical evidence, adapted from the methodology proposed by Ahlemann and Gastl (2007).
Maturity definition	Object maturity (innovation capability).
Maturity logic	Requirements for 'organizational dimensions' and 'performance perspectives', in the form of cumulative conditions by level.
Quality assessment	By multiple perspectives: costs, application, engineering and epistemological, from an adaptation of Frank (2007).
Size	Long (estimated).
Application method	From a specific instrument (not presented in this paper), which may or may not be assisted by third parties.
APPLICATION	
Reuse and customization	The customization can be obtained from the verification of the level of adherence of the performance effects to the organization under evaluation, possibly proposing adjustments or changes in these entities. The other entities of the model are considered universal and do not require customizations.
Use cases	Primary: Non-R&D practitioners and/or low-tech companies. Secondary: The model is considered functional, although incomplete, for companies that practice R&D or are active in environments of high technological dynamism.

In terms of evaluation of the reference model, since it is free and its access unrestricted, it does not present relevant acquisition costs. In terms of training and adaptation, whether for users or new adopters, costs are estimated as low because the model does not require complex tools for its adoption, application and reuse. The model employs a clear set of definition and characteristics to its theoretical and practical domain, prescribing use cases, customization and adjustments over time. Moreover, since the model is oriented to maturity, it is expected to contribute to increased efficiency, reduced costs, improved decision making and greater customer orientation.

Considering the application perspective, there are potential cultural barriers that may hinder the use or adoption of the model. The model is focused on bringing about organizational change. Although the focus is on positive change, it is possible that there is resistance from the employees and from the dominant organizational culture. In terms of model reuse and customization, it can be tailored and customized primarily by adding or modifying the organizational results of innovation capability. This can be done, for example, including aspects related to performance in terms of investment and outcomes of research and development.

6. CONCLUSIONS

This article breaks with a paradigm widely disseminated in the literature when it presents an artifact capable of evaluating, comparing and developing innovation capability in

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low technology companies. The artifact has both theoretical and practical implications. First, in theoretical terms, in addition to offering a detailed representation of innovation capability, its characteristics and main elements, the model integrates the perspectives of maturity and capability in the context of innovation. This theoretical framework can be useful for future studies, whether in the field of process capability or in field of innovation management, or in an integrated vision of both.

In practical terms, the model is an important tool for decision-making, at the management level, in low-tech companies that aspire to broaden their innovation capabilities. Complementarily, the model can be used by institutions supporting the development and competitiveness of companies as an instrument for evaluating and guiding investments, projects and support to companies, especially low-technology ones. The model can also be used, from customizations and adaptations, in other companies and technological contexts, such as in companies that practice institutional R&D.

In summary, the model can foster competitiveness and business performance through differentiations and innovations based on management and performance mechanisms independent of formal research and development practices. However, users interested in changing or modifying the model should consider that most of the entities proposed in it are considered 'universal', that is, they are adherent to companies of different sizes, economic activities and technological complexity. Thus, in order to get a customization without conceptual risks it is recommended to adapt the model's performance effects to the particular scenarios or contexts desired.

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