DESIGN CAPABILITIES AND ENTREPRENEURIAL ECOSYSTEMS: ENVISIONING A NEW ROLE THAT DESIGN CAN PLAY IN MANUFACTURING

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ABSTRACT
This study investigates the relationship between design capabilities and entrepreneurial ecosystems (EEs) aiming to expand the discussion on new product development (NPD) in manufacturing. While the strategic contribution of design to NPD in terms of firms' competitive advantage is widely acknowledged, the rapid technological transformation and disruptions occurring between the production and consumption systems make the adoption of the ecosystems perspective for NPD a promising direction for companies in order to compete and survive. This paper focuses on the manufacturing sector in order to better understand how design capabilities might support manufacturing companies in building EEs for NPD. Therefore, by adopting a bottom-up approach, this study develops a framework that correlates design capabilities to the necessary capabilities for accessing and strengthening entrepreneurial knowledge in EEs. Capabilities correlation derives from the development and interpretation of six case studies that identify design capabilities throughout strategic design experiments for NPD in six food-packaging companies within the Chicago region (IL). A qualitative comparative analysis of the two main representative case studies led to the conclusion that when design capabilities are required to support NPD through EEs, they have possibilities of intervention, but they should be managed on the organizational dimension for the nurturing of sensing, seizing and transforming capabilities of EEs. The framework represents a practical tool for managers that intend to employ and organize design capabilities for NPD by following an incremental innovation and economic adaptation logic.

INTRODUCTION

Design as a strategic resource for new product development
The strategic contribution of design to NPD is widely acknowledged in strategic management and design literature. Design can drive competitive forces of market differentiation and customer value perception; design can support value creation and strategic fit by integrating and mediating between professional domains; design can shape and communicate strategic vision by achieving a holistic view of complex

systems, exploring uncertainty through prototyping and visualization, and providing an innovative perspective by challenging assumptions. Therefore, design is capable of synthesizing and manifesting distributed and diverse knowledge within and outside an organization allowing for superior product and service development.

If design strongly contributes to a company's profitability through acknowledged capabilities for NPD, the exponential growth, speed, diversification, and, most important, the integration of products and services being offered in the marketplace often require an adaptation of design capabilities application to changing conditions (Whitney, 2015). When the production and consumption system is driven by nonlinear dynamics between a high number of agents that interact and co-evolve, design contribution for NPD depends on the capability to embrace and organize more complex and networked interactions. The role of designers changes from authors of proposal development to facilitators of conversations between internal and external agents participating in NPD (Dubberly, 2008; Sanders, 2017).

This adaptation of design practices to nonlinear dynamics for NPD makes design a strategic asset for companies as the context of NPD is rapidly moving from industrial logics of mass production and consumption toward a knowledge economy where the contribution of network agents with diverse specializations is becoming a fundamental prerequisite for competing and surviving (Kelly & Marchese, 2015). The advancements in information and communication technologies (ICT) of the post-industrial economies drive these new rules of competition as they enable fragmentation and further global dispersal of value chain activities (Porter & Heppelmann, 2014; Roos, 2014). Therefore, value creation through NPD often draws on the capability of companies to participate in and manage extra-industry ties and relationships.

New product development in manufacturing

Within a context of rapid change, the manufacturing sector, more than any other, is adapting its production practices and strategies to the technological revolution. Computational characteristics of ICT strongly influence the very notion of product, giving pace to the notion of extended product under which, besides the physical product itself, associated services and knowledge become very important (Camarinha-Matos et al., 2009; Porter & Heppelmann, 2014). Therefore, computation drives the development of capabilities, equipment, processes, and production systems that embed value-adding interactions between diverse and specialized knowledge. With physical fabrication representing only one small part of the whole manufacturing process which includes the whole chain of activities from research and innovation to recycling the provided object, manufacturers are often integrating value-adding innovation within pre- and post-production activities for NPD (Roos, 2014).

Consistently, manufacturing companies develop new, meaningful offers with superior performance drawing on the infinite combination possibilities of products and services by following a product-centric logic of production and consumption to compete and innovate. The product-centric logic relies on the establishment of new standards, namely dominant designs, in terms of forms and features users expect a particular product to take in the future (Anderson & Tushman, 1990). Once a dominant design emerges, the focus of competition shifts from design to manufacturing and the focus of innovation from product innovation to process innovation (Schilling, 2010). As a consequence, the rise of dominant designs as new standards within an industry leads to self-reinforcing mechanisms of technical and market knowledge specialization and, in turn, to the competitive advantage of companies participating in NPD (Porter, 1998; Schilling, 2010).

Under this logic, manufacturing boasts a long tradition of organizing NPD within networks of specialized expertise by increasing industry competitiveness in terms of efficiency. When technical and market knowledge exploitation leads to dominant designs, manufacturing companies adopt territorial models of knowledge-sharing and diffusion for NPD (Moulaert & Sekia, 2003). Once represented by industrial districts (Becattini, 2002) and then evolved into more complex economic and social models like regional clusters (Porter, 1998), the territorial approach for NPD offers a pluralism of interpretation within its wide stream of literature. Nevertheless, the models share invariant outcomes of catalyzing innovation, entrepreneurial initiatives, competitiveness supporting economic growth, long-term development, performance, and success (Scaringella & Radziwon, 2018). By participating in local interactions, manufacturing companies foster the efficiency of the economy of scale through the development of high-performance manufacturing systems.

Although the product-centric logic for NPD in manufacturing is still valid and successful in many circumstances, competition for dominant designs might formalize stability in industrial systems because of self-reinforcing mechanisms of technical and market knowledge specialization toward a defined standard (Geels, 2004). If this logic undeniably leads to a competitive advantage for manufacturing companies, it might be challenging to create long-term value through NPD when technological advancements are developing at speeds never seen before. When technology advances so fast, it can happen that the dynamics of consumption embrace major changes faster than the reaction of the industrial system (Porter & Kramer, 2011; Whitney, 2015). Consequently, manufacturing companies might find it challenging to benefit from economic growth when standards are constantly being disrupted.

An alternative logic for new product development in manufacturing

In this context, approaching economic growth by adopting an adaptive logic for NPD might be a valid alternative for manufacturing companies as the conditions for successful NPD become less predictable. Under this perspective, the economy emerges from its technologies and satisfies demand by drawing on organizational arrangements that reflect actionable technological properties (Arthur, 2013; Kelly, 2010), namely technology affordances (Koch & Windsperger, 2017; Neff et al., 2012). Especially in the current technological panorama, the computational properties of ICT enable the opportunity for manufacturing companies to move toward the creation of broader systems of solutions where industrial boundaries become blurred and the company is just one of the actors participating in and enabling NPD thanks to its highly specialized technological expertise (Porter & Heppelmann, 2014). Therefore, the computational properties of ICT expand the field of action of manufacturing companies by providing them with the opportunity to structure and organize the collaboration and integration of diverse and distributed expertise toward the creation of a sustainable system of solutions.

Consistently, the biological metaphor of "ecosystem" within the business and managerial contexts has gained increasing popularity since the early 90s (Moore, 1993). In its simplest form, an ecosystem could be a combination of different members that interact closely with one another, not only within but also outside the cluster. Over years the literature has described ecosystems under different perspectives (Scaringella & Radziwon, 2018). In one of these, an ecosystem can be defined by its actors, also referred to as an entrepreneurial ecosystem (EE) (Audretsch et al., 2019; Stam, 2017). By acknowledging the varied taxonomy of ecosystems, we find the EEs focus on actors to provide interesting insights for research development when a capabilities lens is

taken into account, as it provides a bottom-up approach for understanding the individual capabilities required for developing new products through the ecosystem logic.

The EEs concept has gained recent popularity among strategy and entrepreneurship scholars and practitioners (Isenberg, 2011; Mason & Brown, 2014; Motoyama et al., 2014) as it represents a new economic development approach that draws on growing entrepreneurial activity in proximity-related contexts. Although EEs share commonalities with territorial models, the former are not defined by the specific resources they contain, such as skilled workers and specialized knowledge of the industry sector nor by technology domains, but by the ability of entrepreneurs and entrepreneurial companies to access and strengthen these resources for NPD by exploiting underlying technological affordances through ties and relationships (E. Autio et al., 2018; Spigel & Harrison, 2018). Therefore, EEs are defined by the process of engagement and interaction that leads to entrepreneurial knowledge access and management over time in a networked context. Although manufacturing companies already develop new products by participating in networks, the purpose of participation in EEs moves from the mere efficiency of the industry to the co-creation of entrepreneurial knowledge for NPD.

One of the main advantages in developing new products through EEs resides in the creation of a shared system that EE participants develop to collectively manage knowledge about the entrepreneurship process (Roundy, 2020; Roundy et al., 2018). Therefore, a primary function of EEs is serving as repositories of entrepreneurial knowledge that help entrepreneurs and entrepreneurial companies to access and strengthen collective knowledge for NPD. This can lead to economic, technological, and societal impacts that draw on the ability of EE participants to access and produce critical resources for other agents in the ecosystem (Audretsch et al., 2019).

Paper contribution

Although design is primarily acknowledged as a competitive asset leading to NPD for a firm's competitive advantage, it also employs capabilities that might potentially support the access and strengthening of EEs resources for NPD. This study aims to expand the discussion on NPD by investigating the relationship between design capabilities and EEs capabilities. We follow a bottom-up approach focusing on the manufacturing companies' interactions with ecosystem resources for accessing and strengthening EEs towards NPD. Specifically, the study develops a framework showing the correlation between design and EEs capabilities for that purpose. The framework derives capabilities from a review activity of both design and EEs literature. Capabilities correlation derives from the development and interpretation of six case studies that identify design capabilities over strategic design experiments for NPD in the context of six food packaging companies within the Chicago, Illinois, region. Such study has led to a wider understanding of how design capabilities might support manufacturing companies in building EEs for NPD. Findings lead to the discussion of current and potential design participation in ecosystems for NPD. Also, the framework represents a practical tool for managers that intend to organize design capabilities for NPD by following an incremental innovation and economic adaptation logic.

THEORETICAL BACKGROUND

The bottom-up perspective on entrepreneurial ecosystems

The fundamental ideas behind EEs emerged as part of a shift in entrepreneurship studies away from individualistic, personality-based research towards a broader

community perspective that incorporates the roles of social, cultural, and economic forces in the entrepreneurship process (Stam & Van de Ven, 2019). From then on, the substantial research promoting EEs has adopted a macro-perspective in the study of the dynamics supporting the growth of entrepreneurial activity that is related to the identification of EEs attributes and their interconnections outputs (e.g., see Isenberg, 2011; Mason & Brown, 2014; Stam & Spigel, 2016). While the interconnections between the attributes of EEs enable resources supporting entrepreneurial activity, entrepreneurs' practices and capabilities in accessing and sustaining these resources represent a fundamental driving force (Roundy & Fayard, 2019; Spigel, 2017b, 2018). This micro-perspective on how entrepreneurs interact with their ecosystem has been recently adopted by several authors in the field. Roundy and Fayard (2019) describe the positive influence of EEs' attributes of encouraging cohesiveness among EE participants for NPD. Cohesion among EE participants is produced from the pursuit of common activities (e.g., creating businesses) and by sharing similar experiences, values and goals (Roundy et al., 2018). When EEs participants engage with EEs forces towards cohesiveness, they improve their ability to act entrepreneurially and to reconfigure and transform themselves in response to new opportunities that arise from changing environments (Roundy & Fayard, 2019; Teece et al., 1997).

The discourse on capabilities for accessing and strengthening an EE is therefore strictly connected to the practices of entrepreneurial companies of sensing, seizing, and transforming in a networked environment. Sensing, seizing, and transforming activities allow an organization to maintain its competitive advantage as technologies and markets change (Teece, 2007). In the context of EEs, the improvement of the three dimensions is reported to be positively influenced by their execution in participation with other EEs members (Roundy & Fayard, 2019).

Capabilities for sensing in EEs

Entrepreneurial companies can improve their ability to identify and assess opportunities (i.e., sensing) by embracing the ecosystem's culture: adopting the "simple rules" (Roundy et al., 2018) of sharing common intentions and narratives about entrepreneurship (i.e., success stories, historical accounts, future-oriented narratives) within a community of entrepreneurs, enabling entrepreneurial companies to engage in EEs human capital in order to search for new opportunities. For this purpose, *storytelling* capability is described as having a determining role for entrepreneurial companies to capture attention, influence the cognitive and emotional encoding of information, and to be memorable (Isenberg, 2016; Roundy & Bayer, 2019; Spigel, 2017). While storytelling influences the legitimacy of entrepreneurial companies to access EEs resources, the ability to discover links between their knowledge and other members' knowledge allows for engaging with the entrepreneurship-oriented human capital of EEs for the purpose of new knowledge creation. By participating in informal interactions and planned events, the *transactive memory* capability of entrepreneurial companies supports sensing activities (Roundy, 2020).

The improvement of sensing activities in EEs not only depends on searching for useful knowledge but also on the learning activities enabled by the diversity of human capital within the social network and the local market. Activities of entrepreneurial learning draw on the *vicarious learning* capability of entrepreneurial companies, the ability to learn from the actions of other entrepreneurs, early-stage ventures as well as mature organizations in the ecosystem (Roundy, 2020; Roundy & Fayard, 2019; Spigel, 2017b). By directly or indirectly observing other EEs members' actions, entrepreneurial companies can proceed with NPD experiments faster and with greater accuracy.

Experimentation activities might involve both entrepreneurial-oriented human capital and local customers. While engaging with other entrepreneurs can support business experiments (i.e., the implementation of new business models) (Roundy, 2020), involving local customers can lead to rapid feedback on the identification of new opportunities and customer needs (Roundy & Fayard, 2019).
These arguments highlight the fact that the human capital available to entrepreneurial companies in EEs makes them more likely to engage in search and more capable of searching. By employing the capabilities of storytelling, transactive memory and vicarious learning, entrepreneurial companies are enabled to access EEs human capital when the identification of new opportunities for NPD is needed.

Capabilities for seizing in EEs

Seizing activities involve mobilizing resources to address and develop opportunities and capturing value from these activities (Teece, 2007). Therefore, entrepreneurial companies evaluate their emerging and existing capabilities and invest in "relevant designs and technologies that are most likely to achieve marketplace acceptance" (Roundy & Fayard, 2019, p. 14). In EEs forces like entrepreneurship support services, the availability of employees with entrepreneurship human capital and professional investment are reported to positively influence seizing activities of entrepreneurial companies (Roundy & Fayard, 2019). Early-stage entrepreneurial companies directly benefit from the engagement with support services and professional investments when investing in necessary technologies, resources, and complementary assets. Mature entrepreneurial companies can favor the development and strength of connections towards entrepreneurial activity incrementation by assuming a mediation role between diverse EEs participants (Lyons et al., 2012). The mediation role requires *proactiveness*, the ability to deviate, innovate, and to mediate among the claims of one group and those of other groups (Feldman & Zoller, 2012). By managing events, by sharing expertise, information and resources among entrepreneurs and investors, and by identifying resources that are necessary when fostering collaboration, mature entrepreneurial companies promote entrepreneurial action. For this purpose, entrepreneurial companies may also act as mentors by providing feedback on assumptions and expectations of participants as well as communication about possible directions for successful NPD. Therefore, *mentoring* as the ability to provide other entrepreneurs with opportunities for growth represents the capability of entrepreneurial companies to foster network connections through learning (Spigel, 2017a).
While proactiveness and mentoring directly support the strengthening of network connections, the ability of *framing diversity* allows for envisioning and articulating a multi-frame perspective towards productive collaboration (Lyons et al., 2012). By reframing multiple views and options for alignment, entrepreneurial companies support the cohesiveness of EEs members when mobilizing resources for NPD. Collaboration in EEs embeds the diversity of participants when experimenting with NPD (Roundy & Fayard, 2019). If the alignment of different perspectives enables collective thinking to develop a common purpose, the ability to understand specialized languages or professions without practicing them namely *interactive expertise*, enables the interpretation of diversity towards the purpose development (Roundy, 2020).
These arguments suggest that successful seizing activities in EEs are dependent on the ability of entrepreneurial companies to build and attract new resources to the ecosystem as well as to support the development of a common purpose. Therefore, while proactiveness and mentoring capabilities contribute to strengthening interconnections,

framing diversity and interactive expertise support the mobilization of resources toward collaboration.

Capabilities for reconfiguring in EEs

Within a context of rapid changes, entrepreneurial companies must be able to respond to signals from their shifting environments; existing resources and capabilities become less valuable as competitors replicate them and as markets shift (Teece et al., 1997). During reconfiguration, entrepreneurial companies in EEs sense signals of change by involving lead users of innovation such as ventures based on "leading edge" technologies that can provide feedback on changes in technologies and consumer preferences and demand (Roundy & Fayard, 2019). Furthermore, in EEs there are typically many entrepreneurs creating businesses across numerous industrial sectors that can inform directions for change (Spigel & Harrison, 2018). In this context, vicarious learning through direct and indirect observations of nearby venture activities encourages the identification and combination of new components for NPD. If vicarious learning allows for sensing initial opportunities as described in the previous section, it supports *reflectiveness* of entrepreneurial companies' actions when reconfiguring is needed. The ability to evaluate and critique the effectiveness of their actions through the redefinition of action-oriented mental maps of a situation represents a fundamental capability for entrepreneurial companies when signals of change towards reconfiguration have been noticed (Feldman & Zoller, 2012; Lyons et al., 2012; Spigel, 2017b).

Once the need for reconfiguration has been noticed, entrepreneurial companies must be able to implement new configurations (Roundy & Fayard, 2019). In EEs, the reconfiguration of activities is often enacted by engaging with other local entrepreneurs who are experienced in early-stage business implementation. As for seizing activities, the development of new configurations requires entrepreneurial companies to engage with EEs participants towards a new common-purpose development, thus employing capabilities of proactiveness, framing diversity, transactive memory, and interactive expertise. This allows entrepreneurial companies to question conventional practices and to push the limits in order to expand the opportunity pool for themselves and the community.

Design capabilities: embracing complexity and organizing collective thinking

Different taxonomies describing the strategic contribution of design capabilities for NPD are reported in the literature, as they reflect different purposes within companies. General taxonomies report the design capabilities' support to a company's internal strategy development for NPD (e.g., see Dell'Era et al., 2020; Stevens & Moultrie, 2011); the design capabilities support companies engaging internal and external actors when they organize participatory activities towards NPD (e.g., see Brandt et al., 2012; Simonsen & Robertson, 2013); and the design capabilities support companies adopting a systems perspective for NPD (e.g., see Conley, 2013; Jones, 2014; Norman & Stappers, 2016). Therefore, design contribution is reported to support different purposes related to the implementation of companies' internal practices towards NPD. Although companies traditionally invest in design capabilities when internalizing NPD practices, the context of design interventions often does not exclude their external environment. Consequently, design capabilities might potentially be employed to follow an ecosystem perspective for NPD, where accessing and strengthening network resources constitute the necessary conditions towards NPD. Under this logic, the literature review presented over this section has focused on the clustering and description of design

capabilities that ontologically embrace complexity and organize collective thinking for NPD. This primary classification has been deemed as necessary for the understanding of design capabilities and EEs capabilities correlation in the following phases of the study.

Design capabilities that embrace complexity

The ability of design to embrace complexity relies on the ways designers visualize and thus simplify the act of framing and communicating complex systems (Weil & Mayfield, 2020). *Visualization* is reported as the ability of making ideas and insights visual and tangible and of representing abstract concepts (Dell'Era et al., 2020). Therefore, designers can make intangible insights and concepts workable by recurring to physical artifacts like sketches, mock-ups, storyboards, and prototypes that embody and communicate abstraction. While designers simplify intangible knowledge both from within and outside organizational contexts (Stevens & Moultrie, 2011), when they capture and represent knowledge embedded outside the company (i.e., social and cultural trends) they drawn on the *knowledge brokering* capability (Bertola & Teixeira, 2003). By translating signals from users' communities and local networks through products participatory observations, designers can mobilize company's internal resources towards NPD directions. However, the development of new products often requires a more integrative approach than user involvement because of the complexity of technological advancements. When technological innovation relies on the collaboration of many different areas of expertise, designers can *integrate knowledge* by mediating decisions about new product criteria through the codification of different perspectives into form, function, value, and meaning (Bertola & Teixeira, 2003; Celaschi et al., 2009).

While on the one hand the ability of creating a visual language leads to a simplification of complex phenomena to their fundamental essences, on the other hand, visualization can reveal and explain patterns of relationships between objects and system components (Dunne & Martin, 2006; Owen, 2007). Consequently, when the relationships between intangible concepts can be visualized, the design capability of *framing* enables systems ordering and patterns synthesis (Conley, 2013; Jones, 2014; Paton & Dorst, 2011). By representing information and data structures, designers can frame systems components in a functional way for assessing the value of arrangements. This ability to establish purposeful relationships between the solution and its context not only relies on questioning solution paths that suggest themselves but also in the identification of new paths through *reframing*. Therefore, designers can widen the solution space by repositioning a concept, solution, or option in different contexts where a new capacity for interaction or use might emerge (Buchanan, 1992; Johns, 2009; Paton & Dorst, 2011). Reframing allows for *envisioning* alternative future possibilities as it opens new spaces of intervention. Designers have the ability to represent alternative scenarios of relatively distant futures that are consistent with an initial intent (Heskett, 2009; Verganti, 2016). For this purpose, *critical thinking* about network partners' different understandings of the context is often required as partners can provide new arguments towards a valuable vision for NPD (Verganti, 2016). Designers are able to interpret network partners' knowledge by challenging their assumptions through the means of 'things to use' (i.e., sketches, mock-ups, storyboards, and prototypes) or by providing them with a broad perspective on a given situation deriving from preliminary research (Verganti, 2016).

By making alternative opportunities for intervention tangible through scenarios, designers create a shared understanding of the possibilities and implications of change.

However, in order to generate long-term value, the real challenge of building scenarios should embed shared values that result not only from the individual consideration of complex phenomena but also from the involvement of diverse network knowledge (Celaschi, 2017; Joore & Brezet, 2015). In this context, selecting a variety of stakeholders for strategic dialogue allows for acquiring diversity of expertise and perspectives towards decision-making (Jones, 2014). Designers *sample* stakeholders with different values, affiliations, and levels of power by mapping how various organizations in an industry compete or complement one another (Roberge & Kumar, 2013). Therefore, the translation of data into graphic forms can reveal relationships allowing the exploration of new areas of opportunity and avoiding time-consuming analyses.

Design capabilities that organize collective thinking

The field of design practice can be viewed as an increasingly complex landscape characterized by numerous kinds of knowledge, as unpredictability and nonlinearity have challenged hierarchical structures of the production and consumption systems. When NPD depends on a wide range of different design inputs, designers are called upon to enable the conditions of stakeholder participation for decision-making (Sanders & Stappers, 2008; Weil & Mayfield, 2020; Wilson & Zamberlan, 2015). Bødker et al., (2017) discuss stakeholder participation by focusing on the designer's *relational expertise*, a critical capability needed when building a sustainable network of relationships which constitute the backbone that supports and potentially sustains NPD projects. Relational expertise has been defined as the ability of designers to bring people together and to provide them with the conditions for collaboration (Dindler & Iversen, 2014). Through the means of traditional participatory design methods (i.e., workshops and prototyping), designers enable participants to engage in the shaping and reshaping of the motivation of the joint activities, leading to the development of tangible artifacts, such as reports endorsed by stakeholders and reorganizations of existing workflow.

In this context, the promotion of dialogue represents a fundamental activity as it fosters the common understanding of participation and collective action (Weil & Mayfield, 2020). Traditionally, designers employ *storytelling*, the ability to create persuasive stories around a shared vision that takes into account the needs, backgrounds, and perspectives of all stakeholders (Bødker et al., 2017). Several methods for storytelling are acknowledged within the participatory design literature (e.g., see Brandt et al., 2012). Using such methods, designers enhance and facilitate dialogue by organizing future workshops where participants jointly envision a future scenario by developing a changing perspective on a present situation.

While promoting dialogue between differences and controversies, designers align stakeholders towards the identification of an appropriate level of purpose. Jones (2014) defines *purpose finding* as the ability to determine agreement when a common purpose need to be identified. In this circumstance, prototypes are the means by which sense is made of the future by collectively exploring, expressing, and testing hypotheses about possible ways of living (Stappers & Giaccardi, 2017). Designers engage stakeholders in prototyping activities where the negotiation of values and concerns happens through dialogue and making, leading to new knowledge development and acquisition for critical reflection in the form of action plans and scenarios. While prototypes in purpose finding aims to bring people together as well as does relational expertise, it is important to highlight that the object of prototyping sessions in purpose finding often addresses the future of an artifact or work practice, not merely the establishment of networks and relationships.

NPD through EEs as a social activity

The EE perspective emphasizes that entrepreneurship is a social activity, as entrepreneurial companies do not identify and develop opportunities in isolation (Roundy & Fayard, 2019); rather, they are dependent on a complex and interconnected entrepreneurial community of resource providers and customers as well as social and cultural forces. Therefore, participating in EEs requires manufacturing companies to employ the described capabilities for accessing and strengthening community interconnections when sensing and seizing opportunities for NPD and when responding to signals of change. Consistently, the literature review has highlighted the design capabilities that might provide significant support when structuring, organizing, and integrating diverse and dispersed knowledge for NPD is required.

The classification of design and EEs capabilities conducted over the theoretical background allowed for identifying the design capabilities employed for accessing and strengthening community interconnections over the case studies, as detailed below in the methodology section.

METHODOLOGY

Context of inquiry: food manufacturing toward local assembly

This study focuses on the food industry, as it represents a complex and adaptive ecosystem with a high number of agents that are interacting and co-evolving, such as agriculture, the manufacturing of machinery and agrichemicals, food processing, wholesale and retail, regulations, R&D, and financial services. The modern food industry is inseparable from daily life, as there is only a small fraction of people that do not rely on it. Therefore, consumer preferences strongly influence the way the production and consumption systems interact. Whereas the dominant production paradigm of customization aims to satisfy consumer demand and lifestyles on a global scale (Jovane et al., 2003), it is widely acknowledged that the globalization of food production has increasingly distanced consumers, both geographically and socially, from food producers and production areas. However, consumers are increasing their awareness of environmental, ethical, and health-related issues when consuming food, reflecting their preferences on customized offers on a local scale (Autio et al., 2013).

In this context, technological capabilities such as Artificial Intelligence, Internet of Things, and automation enable high-quality and high-throughput manufacturing that might connect production and consumption systems by providing local and customized food offers. When consumer demand moves from a global to a local scale, manufacturing might take advantage by leveraging technology affordances toward local assembly optimization purposes. By adopting decentralized production models and highly flexible supply capabilities (i.e., see Unilever, 2021), manufacturing companies have the potential to widen the scope of NPD projects for customized, local food offers of production and consumption.

Under this perspective, being able to structure and organize the collaboration and integration of diverse and widely-distributed expertise represents a necessary condition for manufacturers; here is where design might provide a significant new support. Traditionally, design in the food industry is primary related to the development of products associated with the food, such as packaging (Schifferstein, 2016). While designing packaging products enables improved usage context and the communication of transparent food processing information and brand identity, food packaging

companies might find new opportunities for NPD if they embrace the way food companies develop products for foods preparation, service, and experience.

Research design and methods

Two parallel studies have been conducted to investigate how design capabilities might support the participation of manufacturing organizations in building EEs for NPD. The first study has drawn on the Organizational Models for Innovation course for Master Students at IIT Institute of Design (Chicago, Illinois) as a research platform. The course teaches how to strategically enterprise design strategies by integrating skills, techniques, sensibilities, practices, processes, and strategies that are institutionally and geographically dispersed. The aim of the course is to prepare students to plan, implement, and manage complex collaborative projects using design. The course was held in 2019 under the theme "Local Assembly: The Future of Manufacturing." The authors organized the study by identifying and profiling six food-packaging companies located in the region of Chicago that are showing signals of local production and consumption purposes. We here provide detailed description and analysis of the two main diverse case studies for qualitative comparative analysis. Each company profile was assigned to teams of strategic designers for the development of the case studies that provided the results analyzed and interpreted over the second activity. Strategic designers developed the case studies by learning concepts of NPD in systems from selected readings and by extrapolating key principles that informed the practices for designing the diagrams of organizational models (Figure 1a).

At that point, teams were required to develop a project plan related to each company's organizational model: to design a product/service focusing on local production and consumption purposes by leveraging design capabilities. The project plans were drawn on the 5x5 framework described by Schrage (2014), who defines the framework as a rapid innovation methodology emphasizing lightweight, high-impact business experiments for new value creation in networked industries. By focusing on accessing human capital, experimentation is here a means to explore new value by testing simple hypotheses that extend collaborative capabilities without spending in complex and costly quantitative analyses. The 5x5 framework gives a team of five people no more than five days to come up with a portfolio of five business experiments around the main purpose of experimentation. Consistently, each design team identified a potential product/service to be developed and provided a portfolio of five strategic design experiments in five days, each describing the activities and the design capabilities needed for hypotheses activation.

The second activity focused on the development of a framework allowing for interpreting the design capabilities and their correlation with EEs capabilities for NPD in manufacturing (Figure 1b). The activity consisted of reviewing both the design and EEs literature describing capabilities and related operationalizations. By adopting a bottom-up approach of EEs, the review did identify capabilities allowing for accessing and strengthening EEs. As suggested by the literature, EEs capabilities correspond to different organizational dimensions of sensing, seizing, and transforming when NPD is the focus of analysis. The organizational dimensions have been correlated to the corresponding EEs capabilities and constitute the horizontal axis of the framework. The vertical axis reports the design capabilities that might potentially contribute to NPD through EEs, given their ability to embrace complexity and to organize collective thinking. The framework has been employed as a functional tool for the case studies in order to better understand the correlation of design capabilities and EEs capabilities. Both EEs capabilities and design capabilities have been identified throughout the action

plans by drawing on capabilities' operationalization, and their correlation has been reported in the framework.

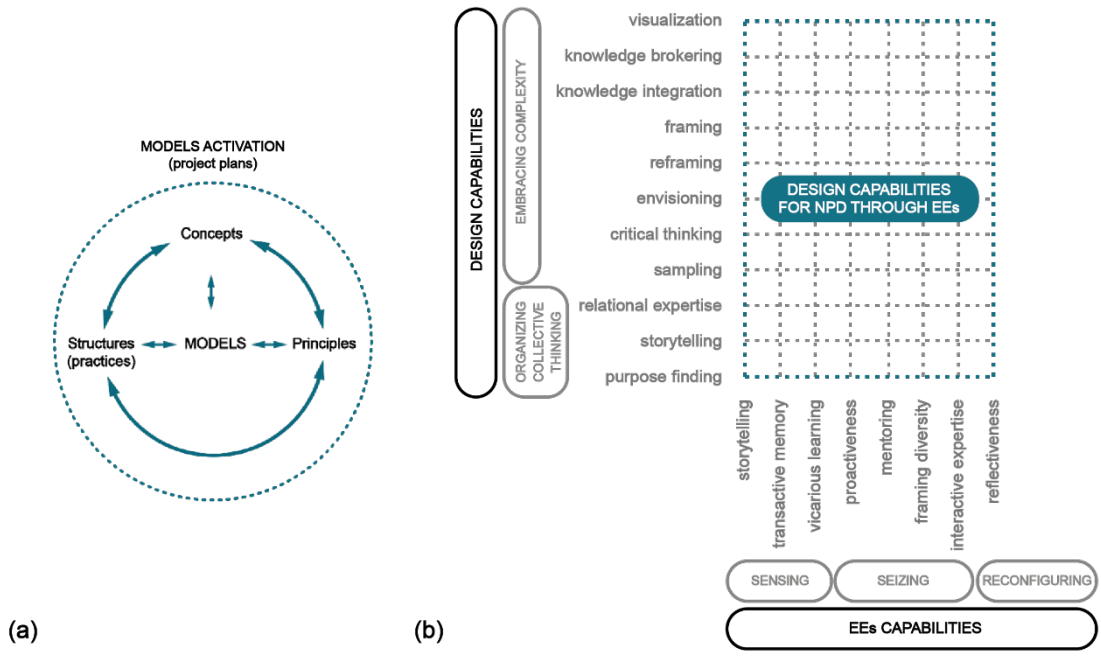


Figure 1. (a) The method applied over the first activity for the case studies development. (b) The framework structure for correlating design capabilities and EEs capabilities toward NPD through EEs.

Companies selection

The six food-packaging companies have been selected because they differ in the production purposes; each is unique in terms of providing products and services that embed signals of local production and consumption toward the concept of local assembly (Table 1).

Companies A and B have been deemed the most representative for the qualitative comparative analysis of the case studies and findings within this paper as they best reflect the two different logics of approaching NPD. While company A aims to implement packaging functionality towards efficiency, company B explicitly requires participation within a system of solutions when producing packaging focused on healthy nutrition.

SELECTED COMPANIES	PRODUCTION PURPOSE	SIGNALS OF LOCAL PRODUCTION AND CONSUMPION
Company A	Packaging functionality	• Packaging for distributing milk in local vending machines • Customizable packaging filling equipment
Company B	Healthy nutrition	• Co-packaging for local and organic food • "Meet the farmer" events for increasing the local production of organic food
Company C	Hybrid packaging supplying	• Large network of manufacturers around the world • Custom and value-added services
Company D	Packaging sustainability	• Virtual packaging assistant for local guidlines on packaging materials restrictions • Sustainable packaging materials for food delivery and takeout services
Company E	Contract packaging	• Flexible packaging machinery • Custom packaging for local manufacturers
Company F	High efficiency filling	• Packaging machinery innovation for custom packaging applications • Upstream and downstream equipment for local farm-fresh vegetables packaging

Table 1. The description of the 6 companies' production purposes and the related signals of local production and consumption. Company A and B are the ones that have been selected for detailed description and qualitative comparative analysis in this paper.

CASE STUDIES DESCRIPTION

The diagrams of the organizational models of companies A and B have been developed by their respective strategic designer teams (Figures 2a and 2b). The diagrams show the position of design capabilities for NPD within a systemic environment.

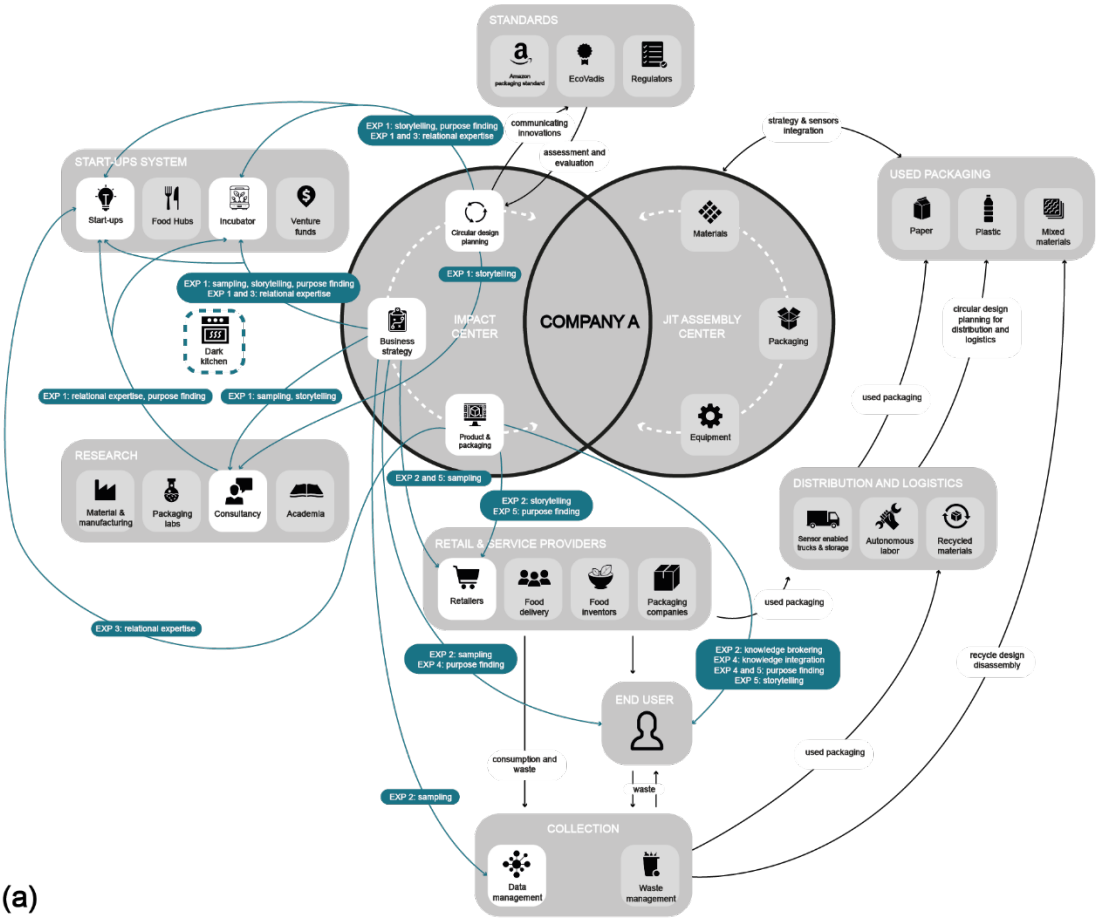
New possibilities for NPD of company A have been explored by developing a 'dark kitchen' model which represents a growing concept in line with the exponential rise of food delivery. The company currently has expert capabilities in packaging design, food manufacturing, insights and product development, Just-In-Time manufacturing, and circular supply thinking. By combining company A's core competencies toward a scalable dark-kitchen model design, a customized, low-cost, efficient, and flexible direct-to-consumer business might be enabled.

Company B has experience in the natural food industry as well as in strategic business operations. The model aims at leveraging the company's capabilities towards the development of an incubation platform to accelerate the growth of entrepreneurial activity and to strengthen the regional food industry. By identifying, investing in, and growing startups, the company might support a bottom-up approach to changing the landscape of the food industry toward the adoption of natural, healthy, and sustainable practices. The sharing of expertise with startups might lead to the creation of profitable companies that support the building of a collaborative ecosystem for societal improvement.

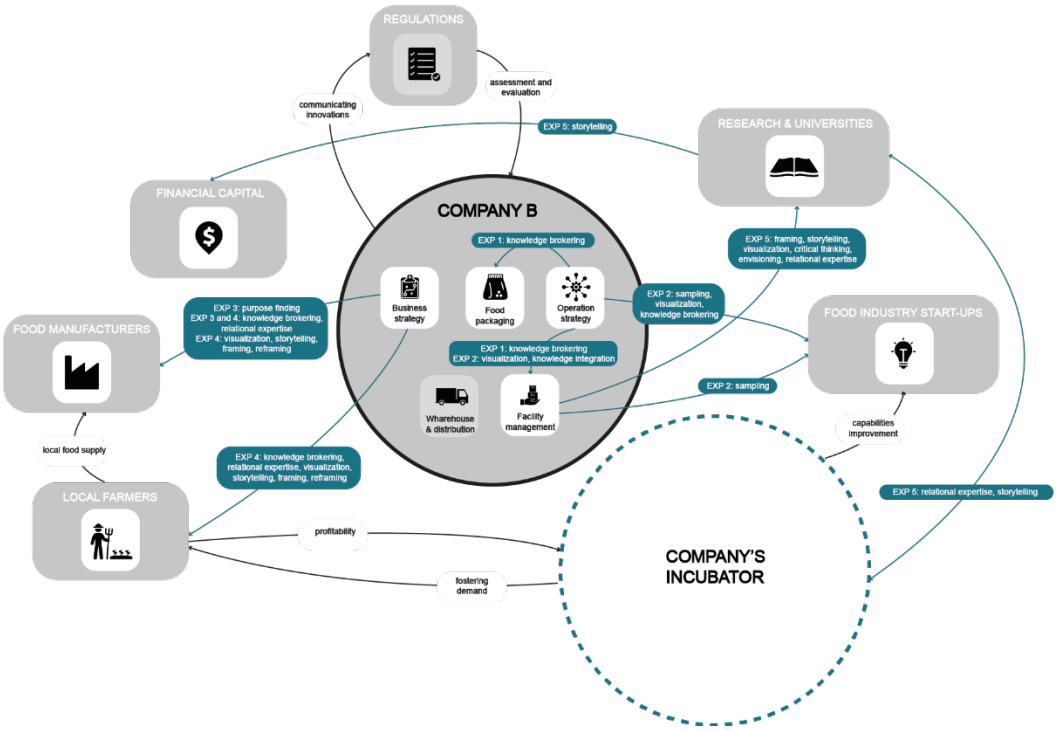
Two project plans based on the developed models have leveraged on the identified design capabilities for the activation of the EEs. Each project plan has been designed by proposing five strategic design experiments and by describing the required activities (Table 2).

CASE COMPANIES	PROJECT PLAN'S GOAL	PROPOSED DESIGN EXPERIMENTS
Company A	Dark kitchen model design	• EXP 1 Co-design a shared kitchen space • EXP 2 Personalized Packaging for D2C Orders • EXP 3 Short-run localized manufacturing for special events • EXP 4 Engage consumers in circular supply chain • EXP 5 Engage supermarkets in circular supply chain
Company B	Incubation platform design for natural food industry strength	• EXP 1 Engaging employees in continuous improvement processes • EXP 2 Which step-by-step will they use • EXP 3 Feeding the incubation: teaching others how to fish • EXP 4 Connecting local farmers with food manufacturers through speed dating • EXP 5 Speeding sustainable knowledge and practices with academia

Table 2. Project plans description for NPD of the case companies A and B that activate the EEs.



(a)



(b)

Figure 2. The diagrams of the organizational models of company A (a) and B (b). Design capabilities (colored labels) have been adopted as the primary reading key.

CASE FINDINGS

The support of design capabilities for NPD through EEs in the case studies has been analyzed by employing the developed framework as a functional tool for the capabilities' correlation. Capabilities' operationalizations, described in the theoretical background section, allowed for the identification of both design and EEs capabilities throughout the design experiments in the project plans. When engaging with systems actors for NPD through EEs, design capabilities should support the sensing, seizing and transforming dimensions of EEs capabilities. While both the case studies largely employed design capabilities for NPD, some key differences are reported when design contributed to NPD through EEs (Figure 4).

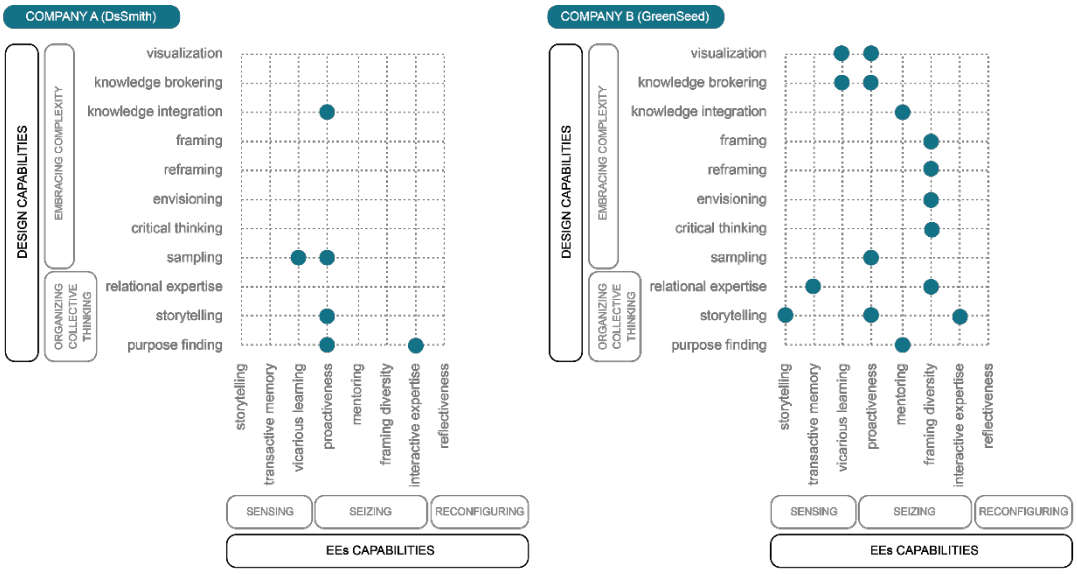


Figure 4. Framework findings of the case companies A (left) and B (right).

Sensing through accessing EEs resources

Sensing new opportunities for NPD in company A has been supported through sampling for vicarious learning (EXP 5). By mapping the local capabilities of retail companies, designers have supported the indirect observation of success stories and historical accounts for exploring possibilities and dealing with external uncertainty. In the case of company B, vicarious learning has been sustained by assessing current engagement practices within the company through visualization in the form of sketches of key information achieved during participatory observations (i.e., knowledge brokering) (EXP 1).

Transactive memory found correlation with the relational expertise of designers when a webinar for NPD opportunities identification within the food industry has been planned, thus enabling the sharing of diverse knowledge in the system (EXP 3).

Last, the ability to capture attention and influence the encoding of information for accessing systemic resources has been sustained by storytelling. The ability to create persuasive stories around a shared vision that considers the needs, backgrounds, and perspectives of all stakeholders allowed for aligning the goal, structure, and content of NPD projects when new connections between university, startups, and investors were needed (EXP 5).

Seizing through strengthening EEs resources

When NPD through the seizing capabilities of EEs had to be supported, the framework reports design capabilities over the case company A to intervene in the sustainment of proactiveness. Specifically, proactiveness in terms of identifying resources for collaboration found a correlation with the sampling capability of design to map industry actors, while the sharing of information and resources toward stakeholder collaboration has been facilitated by codifying NPD criteria mediated by different consumer perspectives through knowledge integration. By involving local customers in a co-design workshop activity, criteria for NPD took shape in the form of packaging prototypes (EXP 4). A different approach for defining new product criteria through collaboration is one of directly involving stakeholders, especially when complex products require diverse and specialized knowledge. Within the project time, proactiveness also requires the ability of managing events that encourage stakeholder collaboration. Designers planned iterative prototyping sessions for the determination of agreement when a common purpose needed to be identified (i.e., purpose finding) (EXP 5). Dialogue and making enabled by the prototyping sessions also supported the ability of stakeholders to understand and interpret the diverse knowledge of participants during the process (i.e., interactive expertise). Storytelling reinforced the alignment of the different perspectives at the end of the activities through debriefing sessions.

Design capabilities of sampling and storytelling for proactiveness have been employed for similar activities over the design experiments of company B. However, proactiveness has been also supported by knowledge brokering and visualization when managing events was required (EXP 1). Aiming at engaging employees for sharing ideas and tracking desirability and feasibility toward the development of the company incubator, the visualization of an improvement framework enabled employee interaction and engagement, while its positioning within a common area allowed for observing and recording reactions and framework usage (i.e., knowledge brokering).

In comparison to company A, where knowledge integration has been employed for codifying product criteria deriving from consumer involvement, company B integrated key information about current engagement practices implemented by employees in the form of paper, video, and online prototypes for mentoring employees toward the engagement of startups, local farmers, and food manufacturers (EXP 2). A webinar was then organized aiming at creating agreements among employees (i.e., purpose finding) in terms of the strategy roadmap-building for engagement (EXP 3).

The engagement of different perspectives in the form of ‘speed dating’ required participants to be able to understand different specialized languages for relationship building (i.e., interactive expertise) (EXP 4). Design capabilities supported interactive expertise through storytelling and by introducing conversation starters on industry topics, thus facilitating engagement through dialogue.

The design capabilities of framing and reframing, critical thinking, and envisioning supported the EEs capability of framing diversity when the creation of the incubator required the engagement of startups and students from a local design university (EXP 5). The connection between startups and students aimed at providing students with the opportunity to apply learning about sustainable practices to real projects. Encouraging the diversity of participants toward a shared vision for collaboration has been supported by the design capability of framing the current challenge with students and startups during an initial meeting, the envisioning of scenarios facilitating dialogue toward collective action, the facilitation of reframing possibilities over a three-day workshop, and critical thinking for interpreting different perspectives and interests geared toward a shared vision. In this context, the relational expertise of designers allowed them to

facilitate negotiations between different viewpoints and objectives among participants by supporting the development of reports endorsed by stakeholders.

Reconfiguring through accessing and strengthening EEs resources

Any correlation is included in the framework, as design experiments report reflection activities that led to NPD project evaluation and iteration, not to the engagement of systems actors such as lead users of innovation as suggested by the EEs literature.

DISCUSSION

Case studies A and B both required the creation of a system of expertise in order to achieve the goals established by the project plans. However, case study A drew on engaging with the knowledge in the system for the improvement of products and services functionality *toward* the 'dark kitchen' model development, while case study B drew on engaging with the knowledge in the system for the enablement of NPD *through* the incubation platform development. Therefore, two different logics of NPD have been applied: case study A reflects the traditional product-centric logic of achieving systemic solutions by improving product/service functionality; case study B adopts an economic adaptation logic toward NPD by building systemic relationships.
Although both case companies required the engagement of system knowledge for NPD, the engagement with resources in EEs relies on capabilities intervention over the sensing, seizing, and reconfiguring of organizational dimensions as a necessary condition for NPD. By investigating the same design capabilities for potential correlations over the case studies, findings show that the adoption of the two different logics have had consequences on the quantity and uniqueness of design capabilities that have been employed over the design experiments of the project plans. Specifically, the interpretation of these differences have led to three main considerations: (a) when engaging system knowledge for sensing opportunities, design capabilities are employed for internalizing that knowledge for NPD (case A) and for accessing that knowledge toward relationship-building for NPD (case B); (b) when engaging with system knowledge for mobilizing resources for NPD, design capabilities are employed for building agreement toward purpose implementation (case A) and for enabling conditions for connectivity implementation between system participants (case B); (c) when continuous adaptation to changing conditions is required, design capabilities for NPD in manufacturing focus on iterating within the project time.

Supporting internalization vs access of resources for NPD

Different purposes of using design capabilities over the sensing dimension have been interpreted from the case studies. When product and service functionality have to be achieved, system relationships are useful for acquiring learning (i.e., vicarious learning) that foster the internal exploration of possibilities. Indeed, indirect observations of entrepreneurial success stories and historical accounts through sampling favored internal activities for sensing new opportunities toward the 'dark kitchen' model development. However, when the purpose for NPD follows an adaptive logic, findings from case B show that vicarious learning might be supported by employing knowledge brokering. This capability has been traditionally employed by designers for observing user behavior while experiencing a product for insight internalization and incremental product improvements (Bertola & Teixeira, 2003). Although knowledge brokering in case B did not directly involve external users but employees, it was supportive for gaining knowledge from employees to use for the engagement of resources in the incubation platform. In this context, visualization capabilities also might support

knowledge brokering, not for incremental concepts visualization but for acquired data and information visualization moving toward collective action.

Accessing resources of EEs requires manufacturing companies to embrace the culture of the ecosystem by sharing common intentions within the EE community. For this purpose, entrepreneurial companies in EEs employ the storytelling capability toward legitimacy building. Case study B shows the design support to storytelling in EEs. Storytelling in design supported the access of entrepreneurs to EEs resources by facilitating the narrative of entrepreneurial paths in the context of discussion groups between startups, university, and investors. This allows for embracing the EE culture and enabling resource access for sensing (Roundy et al., 2018). While storytelling in design is traditionally employed for facilitating the understanding of present situations in problem solving and for supporting a changing in the perspective toward future directions (Brandt et al., 2012), in the context of NPD through EEs it might facilitate the building of legitimacy for resource access for collaboration.

Although sharing entrepreneurial narratives represents a fundamental activity in EEs, entrepreneurial companies must also be able to understand links with useful knowledge in the ecosystem that build toward new knowledge creation. Transactive memory capability is employed for this purpose when entrepreneurial companies share their knowledge through informal and informal interactions with the EE community. Case B organized several webinars that enabled participant knowledge-sharing for the purpose of opportunity identification. The events primarily served to enable conditions for participation toward collaboration for NPD. Within the literature of participatory design this capability of relational expertise is considered relevant when the notion of 'infrastructuring' is taken into account (Dindler & Iversen, 2014). Traditionally, the term 'infrastructuring' has been used to describe the work that goes into creating socio-material assemblies. However, it is interesting to observe how this capability might be supportive also in the context of manufacturing companies for NPD.

Supporting ideation vs implementing connectivity

Network partners' contribution to NPD in manufacturing can be seen as a source for implementing internal ideas or for collaborating. The absence of design capabilities' correlations with framing diversity in case A leads to the consideration that the engagement with network partners has been considered strategic in implementing ideas for new packaging and related service solutions toward the 'dark kitchen' model development. Indeed, by supporting proactiveness, design capabilities of storytelling, purpose findings, and knowledge integration, the company facilitated the implementation of ideas starting from an initial problem with the company assuming a mediation role of connecting different stakeholders through participatory NPD workshops and prototyping sessions. Although this means is considered advantageous in term of expanding the possibilities for intervention of companies (Björk & Magnusson, 2009), case B focused on engaging stakeholders for new connections creation toward NPD possibilities through the incubation platform. Indeed, platforms act as hubs for innovation as they enable some degree of connectivity (Ratten, 2020). The design capabilities of case B supported proactiveness toward the enablement of conditions for engagement and connection in the next activities, thus nurturing the framing diversity capability for strengthening connections in a multi-frame perspective for the platform's successful implementation.

Reflectiveness for continuous adaptation

Findings show no correlation between design capabilities and reconfiguring capabilities in EEs. In EEs, reconfiguration depends on the reflectiveness capability of entrepreneurial companies that embed the ability to engage with lead users for sensing that a change in direction is needed and to engage with other local entrepreneurs for new configurations implementation.

Within the design literature for NPD in manufacturing, the role of design is widely reported when evaluating the qualities of a design product and the effects emerging from the design process are required. Indeed, design capabilities of framing and reframing enable designers to reflect through the implementation of iterative sessions toward an initial intent realization. It might be interesting to analyze how capabilities for sensing and seizing could focus on reconfiguration purposes.

CONCLUSIONS

Within the highly fragmented and nonlinear context of NPD in manufacturing, design might play a strategic role due to its capabilities that embrace complexity and organize collective thinking. Although design is primarily acknowledged as a competitive asset for companies' competitive advantage, its capabilities might potentially enable interventions beyond the boundaries of individual companies by following the logic of ecosystems for NPD. This shift in the perspective of employing design for NPD has been proposed by us as the adoption of an alternative adaptive approach, and might open up new opportunities of intervention for manufacturing companies.

Among the varied taxonomy suggested by the ecosystems literature, we investigated the relationship between design capabilities and EEs, as they adopt a bottom-up approach focusing on ecosystem actors. EEs represent a recent approach to new economic development as they function as a repository of entrepreneurial knowledge that fosters entrepreneurial activity toward NPD. In this context, opportunities for NPD require entrepreneurial companies to access and strengthen EEs resources through sensing, seizing, and reconfiguring capabilities, and this study has shown the potential role of design capabilities in supporting food packaging manufacturing companies. A qualitative comparative analysis between two representative case studies allowed for interpreting the differences in design capabilities employment between the traditional logic of NPD and the adaptive logic when companies need to engage in EEs for NPD. Findings lead to the interpretation that when an adaptive logic of NPD is adopted, (a) design capabilities are employed for accessing system knowledge toward relationship-building when engaging system knowledge for sensing opportunities; (b) design capabilities are employed for enabling the conditions for connectivity implementation between system participants when engaging with system knowledge for mobilizing resources; (c) design capabilities for NPD in manufacturing focus on iterating within the project time when continuous adaptation to changing conditions is required.

It follows that when design capabilities are required to support NPD through EEs, such capabilities have possibilities of intervention but should be managed on the organizational dimension for nurturing sensing, seizing, and transforming capabilities of EEs. The study's contribution highlights an alternative, emerging intervention opportunity in which NPD management can think about design as a strategic resource. We propose the framework as a practical tool for acknowledging and framing design capabilities for NPD through EEs in the manufacturing context. Managers and researchers interested in expanding the topic might contribute by answering the wider research question of how design capabilities might participate in building EEs for NPD.

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