International Journal of Management, Entrepreneurship, Social Science and Humanities, Vol. 8 No. 2 (2025) https://doi.org/10.31098/ijmesh.v8i2.3000

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Research Paper

Understanding Boundary Objects Through Context-Mechanism-Outcome Configurations: A Critical Realist Study of Design-Driven Innovation Capabilities

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Received: January 10, 2025	Revised: April 17, 2025	Accepted: April 28, 2025	Online: May 7, 2025

Abstract

This conceptual study employs a Critical Realist approach with context-mechanism-outcome (CMO) logic to examine how boundary objects facilitate design-led innovation through dynamic capability development. It is conceptually framed by boundary object theory and dynamic capability theory. This study develops a conceptual framework linking different types of boundary objects to key dynamic capabilities (sensing, seizing, reconfiguring) and posits that these shared artefacts and processes act as generative mechanisms driving innovation outcomes across diverse contexts. This CMO-based perspective provides a nuanced explanation of how specific contexts activate these mechanisms to shape innovation results. The primary contribution of this study is a set of theoretical propositions delineating how various boundary objects serve as generative mechanisms in design-led innovation. This bridges boundary object theory with dynamic capability theory and enriches our understanding of cross-boundary knowledge integration and organizational adaptability.

Keywords: *Design-driven innovation; retroduction; dynamic capability; microfoundations; boundary object theory*

INTRODUCTION

Research Background

An increasing number of researchers and businesses have turned to design as a differentiator and source of competitive advantage in the industry (De Goey et al., 2017). Rather than being treated as a peripheral concern of aesthetics, design has become a strategic resource in innovation management (Hernández et al., 2018). This shift is evident in the rise of design-oriented innovation approaches such as design thinking and design-driven innovation (Verganti, 2008).

Design thinking (DT) is also widely regarded as a new paradigm in innovation. It has gained popularity as businesses increasingly emphasize design (Johansson-Sköldberg et al., 2013). It emphasizes understanding user needs, iterative ideation, and prototyping, making design tools accessible even to non-designers in organizations to tackle creative problems to fulfil current market needs (Dell'Era et al., 2020). By contrast, design-driven innovation (DDI) focuses on innovating the meaning of products and services. Instead of pulling insights directly from users, firms proactively propose new product meanings that can shape user desires and open new markets (Verganti, 2008). In essence, DT draws on current user insights to solve known problems. In contrast, DDI explores novel visions to add, extend, or reframe the product's meaning and create unprecedented value propositions. Both approaches position design as central to innovation, but they operate differently: DT leverages deep user empathy, while DDI leverages visionary interpretations of sociocultural trends.

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Effectively implementing design thinking, design-driven innovation, or a mix of the two approaches requires organizations to exhibit ambidexterity capabilities (Zheng, 2018). Organizational ambidexterity is the capability to simultaneously pursue incremental (exploitative) and radical (explorative) innovation. This ambidextrous balance is difficult to achieve because the structures and cultures that support efficiency often conflict with those that foster exploration (Randhawa et al., 2021).

Scholars have argued that ambidexterity itself can be viewed as a dynamic capability. This higher-order capacity enables an organization to reconfigure and realign its resources in the face of change (Cautela & Zurlo, 2012). Determining dynamic capabilities requires understanding organizational structures and management processes. Teece (2007) defined micro foundations as "distinct skills, processes, procedures, organizational structures, decision rules, and disciplines" that support dynamic capabilities.

Recent studies have indeed begun linking design-focused innovation with dynamic capabilities: for example, a study argued that DT and DDI should be viewed as intertwined approaches, proposing the term "design-led innovation" to encompass both and suggest that to leverage design as an innovation strategy fully, firms must develop robust dynamic capabilities (Magistretti et al., 2022a). In keeping with this trend, the dynamic capabilities approach can be seen as promising to provide a better understanding of DDI approaches, the less-known approach of design-focused innovation. For example, Dell'Era et al. (2020) found that intensified variability is growing in design-driven organizations due to the heterogeneity of managerial microfoundations capability.

Although significant progress has been made in understanding organizational design capabilities and their micro foundation, managers are becoming more conscious that organizations fail to conceive and execute outstanding innovation independently (Malsbender et al., 2014). The issue at stake with managerial capabilities and resource configuration in the innovation process is not an individual process (Eisenhardt & Martin, 2000). This issue specifically emerged in design-driven innovation processes, which typically extend across knowledge-based, functional, organizational, and even industry boundaries as firms collaborate with external partners, lead users, and interdisciplinary teams (Dell'Era & Verganti, 2010). Such collaboration causes knowledge boundaries, such as differences in language, expertise, or objectives, that can hinder the sharing and integration of knowledge needed for innovation. Developing dynamic innovation capabilities under these conditions requires effective boundary–spanning mechanisms–i.e., bridging gaps in understanding and facilitating collaboration across the various knowledge domains involved (Hsiao et al., 2012). This is where the concept of boundary objects becomes particularly relevant.

Star and Griesemer (1989) originally defined a boundary object as an entity that is "both plastic enough to adapt to local needs and constraints of the several parties employing it, yet robust enough to maintain a common identity across sites." In other words, boundary objects are tangible or intangible artefacts that serve as shared reference points between different communities, enabling coordination without requiring complete consensus or knowledge overlap. Classic examples include things like sketches, prototypes, models, roadmaps, and databases, which different specialists can all use, albeit in different ways (Carlile, 2002a). In innovation settings, boundary objects have been identified as crucial integrative instruments that help teams exchange and combine knowledge across functional divides.

Research Objectives

Few conceptual models address the micro foundation of the design-driven innovation approach among collaborative stakeholders, how to synchronize each stakeholder in multilateral communications with different perspectives and knowledge, how to share information among stakeholders as a basis for decision-making, and how to organize the learning process to perform explorative innovation activities driven by the design approach. This study makes a two-fold contribution by examining the role of the boundary object for the micro foundation aspect in the meaning of innovation practices and the micro foundation in the management of coordination, which reconfigures the innovation process driven by design.

Research Questions

Overarching RQ: "Which boundary object type and how BO was used to support the different sub-capabilities of design-led innovation?". The research question addressed the contribution of boundary objects across (internal and external) boundary interactions to design-led innovation practices.

LITERATURE REVIEW

Verganti (2008) defined three innovation strategies: market-pull, technology-push, and design-driven. To better serve customer wants, market-pull innovation (or a user-centric approach) explores new technologies or modifies product languages to adapt to current trends. The market is the primary source of innovation, and new product creation directly results from customer needs.

This method assumes that consumer demands are obvious aspects that can be found, documented, and transformed into new products. The technology-push strategy approaches innovation from a new angle. To generate new products, companies must first identify and develop new technologies (Henderson & Venkatraman, 1990; Tushman, 1977). Verganti (2008) proposed the Design-Driven Innovation (DDI) approach to complement the market pull and technological push. According to the DDI, user-centred techniques do not provide radical new meanings. Design-driven innovations are instead recommended for breakthrough products and services. Table 2.1 illustrates the innovation drivers of these three approaches:

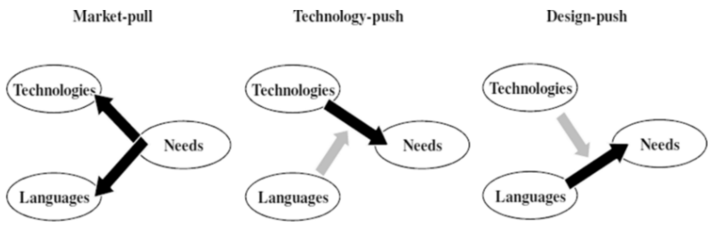

Figure 1. Drivers of three innovation approaches
Source: Verganti, (2003)

Based on the drivers for innovation, we can conclude that the DDI is much closer to the technology push because it does not start from market needs compared to market pull but the knowledge of technology or sociocultural shift that prompts the cycle of these two innovations. The driver differences complement these approaches (De Goey et al., 2017; Verganti, 2008). They note that many businesses have become interested in design-driven innovation (DDI) to generate value over the last decade. Because innovation of meaning is seldom addressed in innovation management research, with the notable exception of sensemaking (Yin, 2009) and foresight theoretical approaches (Tsoukas & Vladimirou, 2001) concerns regarding its relevance in business contexts emerge.

According to Verganti (2009a), innovation is a significant driver of value creation across all businesses for three reasons: first, because any product or service has emotional, symbolic, or utilitarian meaning. Second, highly successful solutions paradigms (e.g., open innovation, crowdsourcing, or design thinking) have been widely adopted and practised across industries, resulting in abundant solutions. When combined with the ease with which technology advances, solutions innovation becomes crowded and progressively loses its differentiation potential. Third, there is a shortage of meaningful innovation to make sense of the abundance of solutions. The commoditization of solutions has resulted from the overuse of design tools, open innovation, and crowdsourcing for solutions and cutting-edge technology. Rather than generating new ideas, the emphasis should be placed on differentiating meaningful solutions from the crowd. Thus, incorporating design into innovation practices brings new meaning and adds value. As a result, businesses and practitioners, particularly those involved in innovation management and processes, may find that incorporating design into their work is beneficial (Verganti, 2009a).

Design-Driven Innovation Vs. User-Centered Design

User-centred design (UCD) means creating products and services that begin with thoroughly analysing user needs. The most prominent example of UCD is design thinking. Based on the user-centric foundations of industrial design, design has an anthropological foundation that enables businesses and others to engage with any real and digital culture located everywhere globally. Moreover, design's capability to learn about these cultural links and adapt them to new product and service ideas enables it to generate income and profits in an increasingly unstable global economic climate (Gumulya et al., 2023). This unique approach to design is referred to as design thinking, a creative process that entails exploring novel potential solutions. Rather than enhancing current solutions, this approach examines difficulties and the possibility of creating new, user-centric solutions to address them. Design Thinking is often described as combining empathy, creativity, and logic to more effectively address user demands and facilitate the development of novel ideas. As such, Design Thinking is a creative process emphasising the creation and synthesis of ideas rather than their deconstruction (Dorst, 2011)

In comparison, Design-driven innovation has been defined as the gradual and radical innovation of a new market, product, and service meaning. It began with listening to socio-economic signal changes and interpreting them to develop a new meaning for the product or service. An organization can gain essential and unique knowledge to guide product innovation by interviewing and studying customers. UCD has demonstrated the importance of design in organizational processes to get closer to users and better understand their needs. While DDI processes have led to increased user awareness innovations, they lack the resources to look for potential scenarios or "what could be" independently. This means that user-driven innovation aims to design products that better meet existing consumer needs instead of changing the essence of a product recognized as an essential product or differentiating service (Dell'Era et al., 2018).

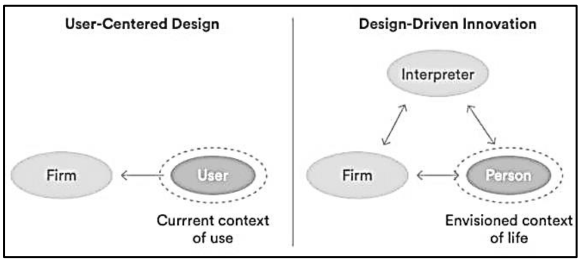

Figure 2. UCD vs. DDI
Source: Verganti, (2009a)

Design Discourse

Verganti (2009a) analyzed design thinking and claimed that managers who embrace design thinking are too focused on a codified, step-by-step manual. In order to produce radical innovations, a company's top managers must become immersed in what Verganti termed the design discourse. Verganti's DDI process involves listening to, interpreting, and addressing the design discourse. The design discourse is an exclusive circle of radical researchers and key interpreters that exchange insights, interpretations, and proposals through artwork, studies, speeches, prototypes, and products. This implies understanding where this knowledge lies and how to internalize it.

He provided examples from Italian manufacturers, recognising that their firms were immersed in this distributed network of actors who explored future meanings and influence. These manufacturers recognize that most of these actors share the same problem, as shown in the graph below:

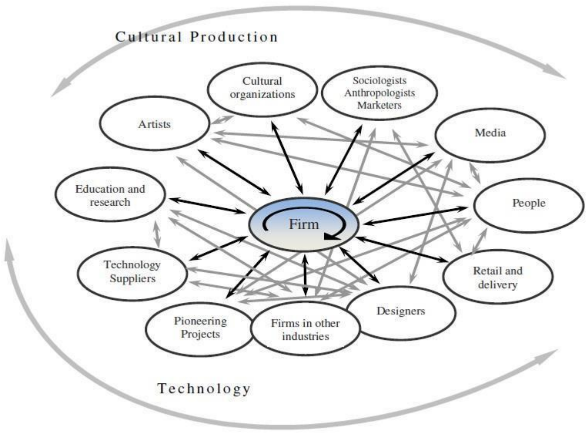

Figure 3. The Design Discourse Surrounding a Firm
Source: Verganti, (2008)

The Design-Driven Innovation Process

The design-driven innovation process necessitates proximity to interpreters. It capitalizes on individuals' capacity to comprehend and affect how they interpret a product or service's meaning. As previously mentioned, the fundamental competency for design-driven innovation is active participation in the design discourse, particularly in the design-driven innovation process, which is divided into three distinct phases: listening, interpreting, and addressing.

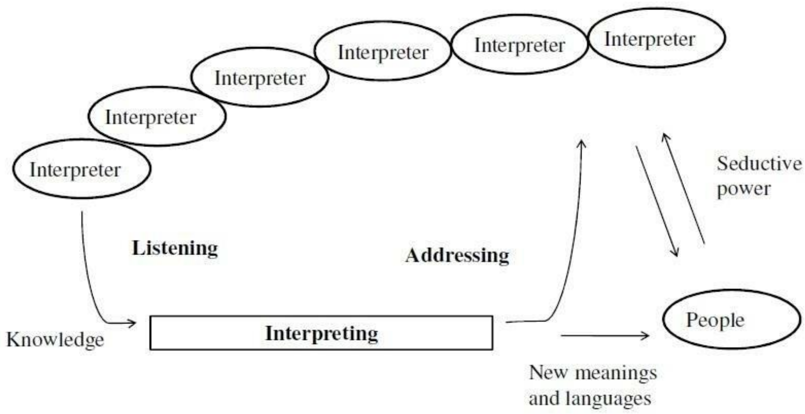

Figure 4. The Design-Driven Innovation Process
Source: Verganti, (2009a)

Listening

The listening activity entails gaining information on new items' prospective meanings and languages and engaging critical interpreters of the design dialogue. A successful design-driven innovation firm will identify important interpreters, recruit them ahead of rivals, and establish a privileged relationship with them. In recent years, the literature on design management has seen a growing enrichment, with contributions characterized by increased scientific rigour, a wider variety of empirical data, and an increasing emphasis on the more exact and bordered elements of design process structure.

Interpreting

This phase involves developing an original vision and a new proposal for a fundamental shift in meaning and language. In addition, it entails compiling and reinterpreting data gleaned from the design discourse while conducting internal research and experiments to generate radical innovation. To accomplish this mission, the company requires an effective process for disseminating knowledge from the design discourse and transforming it into concrete visions. It is important to note the differences between internal and external interpreters in these roles. External interpreters play roles as interpreters of insight derived from communities and communicate new ideas on meaning innovation to the formed company.

Addressing

First, design discourse must be addressed by disseminating the new vision to as many interpreters as possible. The second goal is to determine the most appropriate means by which interpreters can discuss and then internalize the new proposals that have been made. When introducing a revolutionary new product or service, advertising is not the best medium to convey it. Design-driven companies should take a different approach, relying on interpreters present in the design discourse. These companies should seduce people because they influence how they interpret things and how new proposals are presented (see Figure 5 below). As a result, interpreters may be said to have seductive power because they impact how people interpret and assign meaning to products.

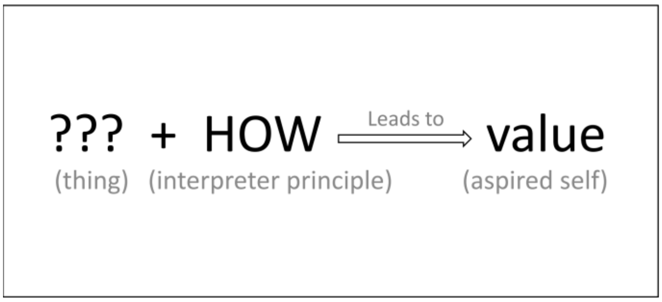

Figure 5. DDI Diffusing Process
Source:(Goto et al., 2018)

Ambidexterity- and Design-Driven innovation

Ambidexterity can be defined as a firm's capabilities to maximize the efficiency of current business operations (i.e., exploitation) while simultaneously seeking new opportunities and radical innovations (i.e., exploration) (Raisch et al., 2009) in other words, as the capacity of a firm to pursue competing strategic orientations concurrently (Han et al., 2022). It should guarantee that firms can conduct exploratory procedures for sustainable development while optimizing returns on existing business practices (Aragón-Correa& Sharma, 2003). Balancing inherently disparate sets of activities for exploitation, which includes "refinement, choice, production, efficiency, selection, implementation, and execution" (March 1991), and exploration, which includes "search, variation, risk-taking, experimentation, play, flexibility, discovery, and innovation," is therefore central to ambidexterity. Exploration and exploitation are mutually exclusive because they are motivated by opposing goals (Andriopoulos & Lewis, 2009). Therefore, finding a compromise is unavoidable. Occasionally, ambidexterity is also used to allude to the continual balancing trade-offs between several options, such as the concurrent use of the paradoxical UCD and DDI approaches in the innovation process. In recent years, the literature on design management has seen a growing enrichment, with contributions characterized by increased scientific rigour, a wider variety of empirical data, and an increasing emphasis on the more exact and bordered elements of design process structure.

Urgings to practice design consciousness and encouragements to use design as a tool for competitive advantage or embrace a distributed vision of design across the business have been found in the literature on design management. As a result, the structure of the design process has been examined from various angles and interpretations, often in an indirect manner, emphasizing the implications of design-led creative models on organizational logic. One of the investigation's focal points is the 'Ambidextrous organization' frame, which has been used to report on the design management system's tensions. The organization of design has been studied from a variety of perspectives: some early contributions examined the inter-sectoral technology transfer dynamics operated by design consulting firms (Hargadon & Sutton, 1997) and defined such organizations as "technology brokers'; other studies defined the designer's role as "language brokering" (Verganti, 2003) and still others have emphasized networking dynamics (Capaldo, 2007). This dimension reflects the capabilities that each collaboration and design approach has developed in the prior literature for better understanding the mechanisms underlying knowledge sharing, integrating, and proposing new meanings in the design discourse, ultimately leading to the seduction and dissemination of the new product meaning to a broader population.

Bridging Dynamic Capability and Boundary Objects

Scholars have begun to see organizational design skills as dynamic because they enable organisations to detect and grab new business opportunities (Felin & Powell, 2016) and reorganize resources to take advantage of these changes (Liedtka, 2020). Three primary abilities comprise invention as a dynamic capability according to (Teece, 2009): (a) Sensing is the capability to identify current market demands or opportunities. Sensing skills manifest in three primary functions: scanning, assessing, and detailing. (b) Capability for seizing is required to investigate many service options and choose one or more viable solutions. The following three tasks distinguish seizing abilities: solution creation, assessment and selection, and solution detailing. (c) Reconfiguration capabilities are used to implement the final solution inside the company, whether it is a new or modified innovation practice.

Because such sensing, seizing, and reconfiguration are critical characteristics of UCD and DDI, we refer to each as a dynamic capability. The research shows that these skills represent two different design approaches (Dell'Era et al., 2018). As the name indicates, UCD places users at the centre of the experience routines, which allows an organization to continually refresh and modify its repertoire of knowledge and understanding of users. The DDI promotes awareness of the larger environment in which a user exists and focuses on recognizing emergent sociocultural models and signals produced by technology and growing social constraints (Dell'Era et al., 2018). However, according to Barney and Felin (2013) few studies explain the roots of the macro level's dynamic capability due to people and their interactions at the micro level. They contend that distinct collective dynamic capability outcomes at the macro/organizational level must be unpacked from the micro foundation to comprehend aspects such as organizational capability. Individual, organizational, and network levels of study may be used to investigate the micro-foundations of dynamic capabilities (Eisenhardt & Martin, 2000; Rothaermel & Hess, 2007; Salvato & Vassolo, 2018).

Several design-led capability micro-foundations have been identified from the previous theoretical frameworks and empirical evidence, such as the capability of embracing ambiguity to reconfigure knowledge and reframe the problem and solution by abductive and holistic thinking capability. From the interaction perspectives of speculating, envisioning, and debating, capabilities are needed so organizations can have the ability to change and experiment iteratively, which must be supported by an appropriate and flexible structure (Magistretti et al., 2022b). A more complete picture of the design-led micro foundations is presented in the table below:

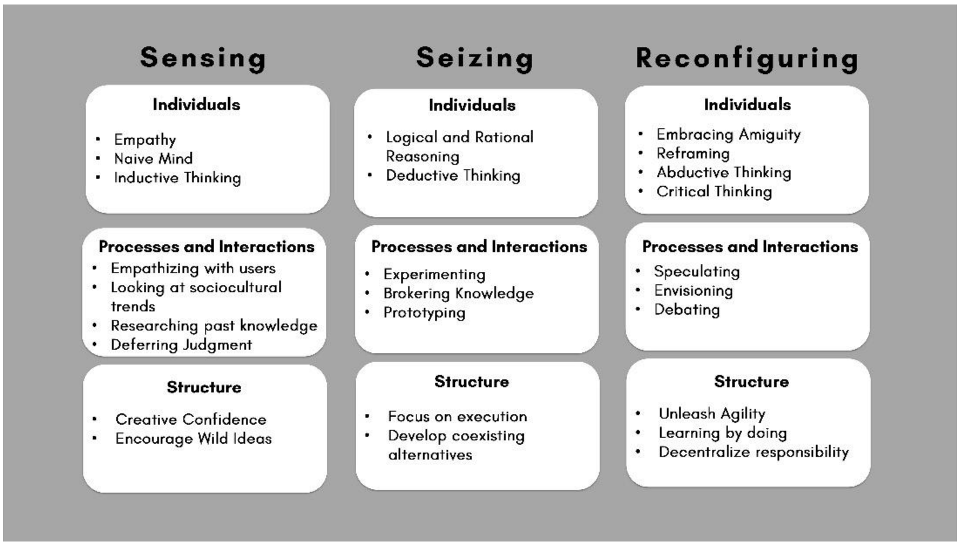

Figure 6. Figure of design-led microfoundation, adapted from Dell'Era et al. (2020)

Interactions at the micro-level constitute the existing organizational boundaries, both internally and externally. From a conceptual standpoint, an organization has external boundaries that separate it from external factors, such as suppliers and consumers, and internal boundaries that serve as a demarcation line between divisions. They are often observed when knowledge is dispersed unequally (Star & Griesemer, 1989). Such scenarios occur during collaborative work when functionally varied, temporally and geographically dispersed team members are required to collaborate on a single job (Tushman, 1977). Boundary-spanning procedures are required to address these issues. They are "an organization's capacity for creating, transferring, and integrating information across boundaries" (Helfat et al., 2009) and are often a critical component of organizational design. Boundary crossing is critical for information collection operations to connect new information to existing knowledge, mainly when the goal is to stimulate creativity (Caccamo et al., 2023). From a technology standpoint, boundary objects (BO) represent a method for implementing boundary-transcending techniques. Their objective is to eliminate current barriers to information sharing (Carlile, 2002b). Carlile (2004) asserted that BO facilitates knowledge sharing in the context of innovation. To overcome various barriers, many sorts of boundary objects are discovered by a taxonomy that classifies objects into four categories: repositories, ideal types, maps, and standardized forms (Carlile, 2002b).

Repositories provide a shared database (like data, measurements, or labels) that can be used to build a shared understanding of shared definitions and values for cross-boundary problem-solving, like when people from different backgrounds collaborate. This type of boundary object is suitable during an innovation process because the information needed for impulse recognition and solution development can be collected by the people involved and stored in an organized way (Blomqvist & Levy, 2006). Also, during the reconfiguring phase of an innovative concept in the organization, repositories can be used to document the roll-out process and show other actors how things have changed.

The second type is to make complex or straightforward representations (abstractions) of things like models, called ideal types (Dell'Era et al., 2018). In the early phase of an innovation process, ideal boundary object types can be used to show and explain ideas or concepts in an easy-to-understand and abstract way. When the product is used in later stages, a general procedure demonstrating what each person must do can be presented.

The third type of boundary object is a map that shows how groups, functions, or organizations are connected and how they already have boundaries. These examples demonstrate how cross-functional problem-solving efforts depend on each other for resources, deliverables, and deadlines (Carlile, 2002b). In this way, a detailed description of the dependencies in the innovation process is given—the benefits of this type of boundary object increase as the innovation process advances. Forms and procedures used to establish standard work practices and a common format for problem-solving across borders are used in this fourth step. This format is designed so that each definition or categorization of differences and possible consequences is easy to understand and share and less challenging to deal with in different settings (Carlile, 2004). For example, in a collaborative environment, such as when different people across boundaries work together on innovation, standardization parts are needed to communicate about and agree on the consensus reached. Standardization forms and procedures can be created for each sub-capability or micro foundation. Therefore, BO can be used as a starting point for further refinement.

This study includes seven propositions linking the features of boundary objects with the dynamic capabilities of the design-led innovation approach, which are as follows:

1. Boundary objects produce a cognitive space conducive to resource orchestration; the resulting "bridge model" primarily supports the "sensing" and "seizing" phases.
2. Boundary objects allow cumulative access to data, information, and expertise, thus empowering a team (cf. shared and common understanding), particularly in the "seizing" process.
3. Boundary objects cause convergence among stakeholders who use them ("seizing"), especially when developing an innovation trajectory.
4. The boundary object's cognitive space and the consequent mutual understanding reduce resistance to change, influencing the "reconfiguration" phase, and necessitating special management activities, including representing and translating ideas.
5. The designer portfolio and relational assessment management are significantly important. Design management implies the need to manage the interaction.
6. The cognitive approach is the difference between UCD and DDI. Several previous studies suggest spatial and temporal structure separation when conducting a parallel UCD and DDI process; hence, analysis via boundary object
7. Envisioning capabilities are important in design-led innovation, consistent with managing experimentation in the innovation process.

We now synthesize our research model based on the aforementioned theoretical foundation, addressing the constructs and their linkages. We argue that using boundary objects enables organizations to transcend organizational boundaries, thereby strengthening the micro foundation for design-led innovation skills (shown in the Figure 7 below):

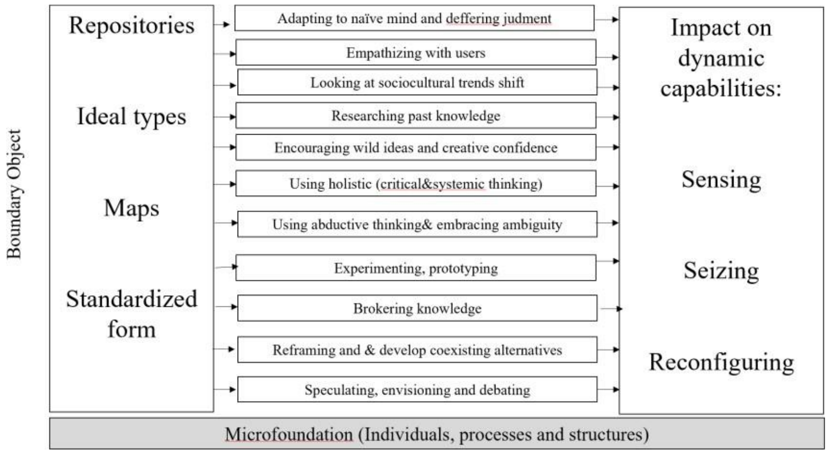

Figure 7. Initial Theoretical Framework (TF1)

RESEARCH METHOD

Critical Realism Approach in Design-Driven Innovation Context

This study is grounded in Critical Realism (CR) as its philosophical paradigm. CR posits a stratified ontology in which reality operates at three distinct but interrelated levels: the empirical (this research experiences and observations), the actual (events that occur, whether observed or not), and the real (underlying structures and mechanisms with causal powers) (Bhaskar, 2013). In this view, observable phenomena in design-driven innovation—such as the success or failure of innovation projects, team behaviors, or the effective use of boundary objects—are not just surface events but manifestations of deeper, unobservable mechanisms (e.g., organizational routines, power dynamics, or knowledge-sharing structures) that exist in the real domain (Mingers, 2004).

This ontological stance is especially well-suited for studying design-driven innovation practices, which are complex, interdisciplinary, and context-dependent. It allows the research to move beyond mere description of what is happening in design teams and investigate why it is happening by probing the causal forces at play beneath the surface. In other words, CR provides a foundation for examining how and why boundary objects influence innovation outcomes, acknowledging that these influences stem from deeper social and material structures, rather than just visible interactions.

Methodological Tools

To operationalize Critical Realism, this study employs a set of complementary methodological tools: reproduction, abduction, multiple case study research design, and multi-level analysis strategy. These tools, in combination, enable research to uncover hidden structures affecting design practice and build robust explanations.

Retroduction

CR's distinctive mode of inference is retroduction, which involves reasoning backwards from observed phenomena to theorize about the conditions that could have generated them (Danermark et al., 2019). Rather than simply inductively cataloguing patterns or deductively testing hypotheses, this study uses retroductive reasoning to ask: "What must be true about the underlying structure or mechanism for this observed event to occur?" (Easton, 2010).

In practical terms, this study will analyze the case data whenever there is a noteworthy outcome or pattern (for example, a boundary object repeatedly leading to improved team alignment) by employing retroduction to hypothesize what hidden mechanism might explain it (e.g., the boundary object functions as a transdisciplinary communication channel enabling knowledge integration).

Abduction

Abduction in qualitative research entails reframing or reinterpreting empirical observations using theoretical insights or new concepts (Sayer, 2010). This is crucial when studying an emergent field like design-driven innovation, where researchers must often make sense of complex, context-rich situations. In this research analysis, abduction is used to connect our empirical findings with extant theory in design and innovation. For example, suppose a participant describes an unexpected use of a prototype that sparked a radical idea. In that case, this research will abductively reason about this event by drawing on boundary object theory or innovation management concepts to interpret its significance. This process will help ensure that emerging explanations are data-driven and theoretically informed.

Abduction and retroduction work in tandem: Abduction helps broaden the perspective and suggest possible explanations by linking data to theory. In contrast, retroduction helps deepen the explanation by evaluating which of those explanations points to a plausible underlying causal structure (Danermark et al., 2019).

Case Study Logic

Given the CR emphasis on context and mechanism, this study employs a qualitative multiple-case study design to investigate design-driven innovation in its real-life context. (Eisenhardt, 1989a). A case study strategy offers rich, contextually grounded data and aligns with CR's intensive research preference for in-depth explanation. By examining multiple cases, this research can use replication logic to strengthen the explanatory power of our findings (Yin, 2008).

Specifically, the study will select several innovation projects or organizations that practice design-driven innovation, using either literal replication (cases with similar conditions to see if the exact mechanisms recur) or theoretical replication (contrasting conditions to observe variation). This design increases the robustness of the insights by allowing cross-case comparison and extension of the theory.

Multi-Level Analysis.

Finally, this study's methodological approach incorporates an explicitly multi-level (stratified) analysis consistent with CR's ontology. This means that this research analyzes the data by looking at phenomena at different levels of reality and organization and examining the relationships between those levels.

This multi-level perspective is closely tied to the CR idea of stratification: it ensures that this study does not analyze events in isolation but always about the broader structures that shape them. (Sorrell, 2018). The analysis moves up and down these levels to build explanations. For example, insight at the micro level (e.g., miscommunication between two stakeholders) may prompt the study to examine a meso-level mechanism (perhaps an absence of a common language or a siloed organizational structure that a boundary object must overcome). Conversely, recognizing a meso-level condition (e.g., an organizational culture emphasizing collaboration) may help explain why certain micro-level interactions (like rapid iterative prototyping across departments) succeed in one case but are absent in another.

By structuring the research inquiry in this multi-level way, this study aligned with CR's commitment to contextualized explanation—acknowledging that causal mechanisms (real level) manifest through particular events (actual level) that are observed in practice (empirical level) only under certain enabling or constraining conditions (Moghadam-Saman, 2019).

Data Collection

This study collects in-depth qualitative data to investigate the proposed cases that capture the observable phenomena and the underlying context. Primary data will come from semi-structured interviews and direct observations in each case. Thus, the researcher will conduct interviews with key stakeholders involved in design-driven innovation projects–designers, product managers, engineers, and other members of cross-functional innovation teams.

These interviews will probe participants' experiences, perceptions, and interpretations of how boundary objects (such as prototypes, design sketches, storyboards, or other shared artefacts) facilitate knowledge integration and innovation. The researcher will complement interviews with observations of innovation activities (e.g. design workshops, brainstorming sessions, prototype demonstrations) to witness how boundary objects are used in practice.

Furthermore, this study will employ the Context-Mechanism-Outcome (CMO) configuration logic from realist evaluation as a guiding framework during data collection (Pawson & Tilley, 1997). In practice, this means we frame our interview and observation protocols to identify: the contexts (C) of each case (such as team composition, project type, andorganizational setting), the candidate mechanisms (M) at play (e.g. how a boundary object mediates between different knowledge domains), and the innovation outcomes (O) observed (e.g. successful integration of new product concepts or conversely, misalignment among stakeholders.

Analyses of Data

During analysis, this study will iteratively move between theory and data—a process sometimes referred to as theory matching or a retroduction cycle—until a coherent explanation is reached for each case. Then, cross-case analysis and stratified analysis bridge the gap between observable design-led innovation practices and the invisible generative forces that shape them.

Abduction and retroduction usage connect the empirical manifestations of boundary objects in action to the real causal powers they exert within specific actual contexts and events. This study also draws on existing critical realist methodological guidelines (Wynn & Williams, 2012)to ensure quality criteria, such as causal adequacy and analytical generalization, are met. For example, this research will follow the principle of explicating context by richly describing each case environment and the principle of causal explanation by focusing our analysis on explaining how and why observed innovation outcomes occurred through specific mechanisms.

The outcome will be a set of context-mechanism-outcome explanations that advance theory (by revealing how and why boundary objects function as enablers of dynamic innovation capabilities) and provide practitioners with insight into the often-hidden forces influencing their innovation efforts.

FINDINGS AND DISCUSSION

Coding Framework and Thematic Structure

To analyze qualitative data, this study employs a hybrid thematic coding framework combining deductive codes derived from theoretical propositions and inductive codes emerging from empirical observation. The initial coding framework was structured around the three core phases of dynamic capability—sensing, seizing, and reconfiguring—and the four types of boundary objects identified in prior literature (Carlile, 2002; Star & Griesemer, 1989). For example, codes such as "cross-functional alignment," "knowledge translation," and "design artefact use" were aligned with seizing capabilities, while "vision diffusion" and "interpretive alignment" were linked with reconfiguration.

As themes emerged, axial coding was used to group them under broader categories that reflected patterns in actor interaction and artefact usage across boundaries. This provided a structured lens to explore how context-mechanism-outcome (CMO) configurations unfold in design-led innovation.

Applying Retroduction to Identify Causal Mechanisms

The reproduction analysis proceeded iteratively by comparing emergent empirical patterns with theoretical constructs and then reasoning backwards to infer deeper causal mechanisms. Proposition 3 provides a concrete example, positing that boundary objects generate stakeholder convergence, especially when developing an innovation trajectory. After initial pattern matching, this study conducted a retroduction inquiry: What must be true about the innovation environment for these outcomes to emerge consistently?

From this line of reasoning, the researcher inferred a "translational mechanism of shared vision construction"—wherein boundary objects are expected to act as containers of information and as relational mediators, enabling epistemic alignment among stakeholders with heterogeneous knowledge bases. This mechanism was not directly observable but was supported by multiple layers of data: convergent interview insights, contextual observations of how prototypes were modified collaboratively, and supporting documents presenting consensus-based decision-making. Through successive refinement across cases, this retroduction process evolved the proposition from a descriptive to a generative explanatory model, articulating what occurred and why it occurred under specific contextual conditions.

Consistent with CR's expectation of rival explanations, this study critically compared emergent mechanisms with those proposed in prior literature. For instance, Hsiao et al. (2012) suggested that cross-boundary innovation outcomes can result from adaptive social learning independent of artefacts. Similarly, Carlile (2004) emphasized that boundary objects are repositories of structured knowledge rather than relational agents of interpretation.

Contextual Generalizability

This study shares partial resonance with research in other sectors. For example, in health informatics, boundary objects support cross-disciplinary collaboration (Terlouw et al., 2022). However, this study highlights a distinctive feature of design-led innovation: the emphasis on meaning-making and future-oriented exploration rather than knowledge transfer or coordination.

Consequently, the observed mechanisms—such as the aforementioned interpretive convergence—may be contextually unique to creative, open-ended innovation settings. Although similar in form to mechanisms in other domains, their activation conditions and functions differ, especially in how they mediate ambiguity and foster emergent interpretations. This insight suggests that although boundary object theory has cross-domain relevance, its explanatory application must be calibrated to the epistemic culture of the field (Nicolini et al., 2012)

Contribution and Theoretical Novelty

This study makes several novel contributions to theory and practice. First, it extends Boundary Object Theory by emphasizing artefacts' generative and interpretive roles—not only as static repositories of knowledge but as dynamic mediators of shared meaning in design practice. This study demonstrates the practical value of retroduction and CR-based inquiry in surfacing otherwise unobservable structures that shape design outcomes. By showing how boundary objects act as material anchors for shared cognition and collaborative agency, this study contributes a nuanced, mechanism-based explanation that enriches existing models of innovation and collaboration.

Second, it refines the understanding of design-driven innovation by identifying causal mechanisms that link micro-level interactions (e.g., boundary negotiation through prototypes) with macro-level innovation capabilities. Thus, design-driven innovation theory can be advanced by specifying how microfoundational capabilities are enacted through artifact-mediated interaction, offering a more granular explanation of how sensing, seizing, and reconfiguring unfold in collaborative settings, especially when meaning-making innovation processes are involved.

Third, it demonstrates the practical value of retroduction and CR-based inquiry in surfacing otherwise unobservable structures that shape design outcomes. By showing how boundary objects act as material anchors for shared cognition and collaborative agency, this study contributes a nuanced, mechanism-based explanation that enriches existing models of innovation and collaboration. Thus, retroduction as an analysis tool enables research beyond surface pattern recognition, offering a replicable approach for future research into innovation ecosystems.

In sum, the study explains how and why boundary objects support design-driven innovation under varying organizational conditions. This study addresses a key gap in the literature on dynamic capabilities by illuminating artefact-mediated coordination mechanisms. It contributes to CR-based research by illustrating how conceptual rigour and empirical iteration can yield robust explanatory models in innovation and design management science.

The Research Framework

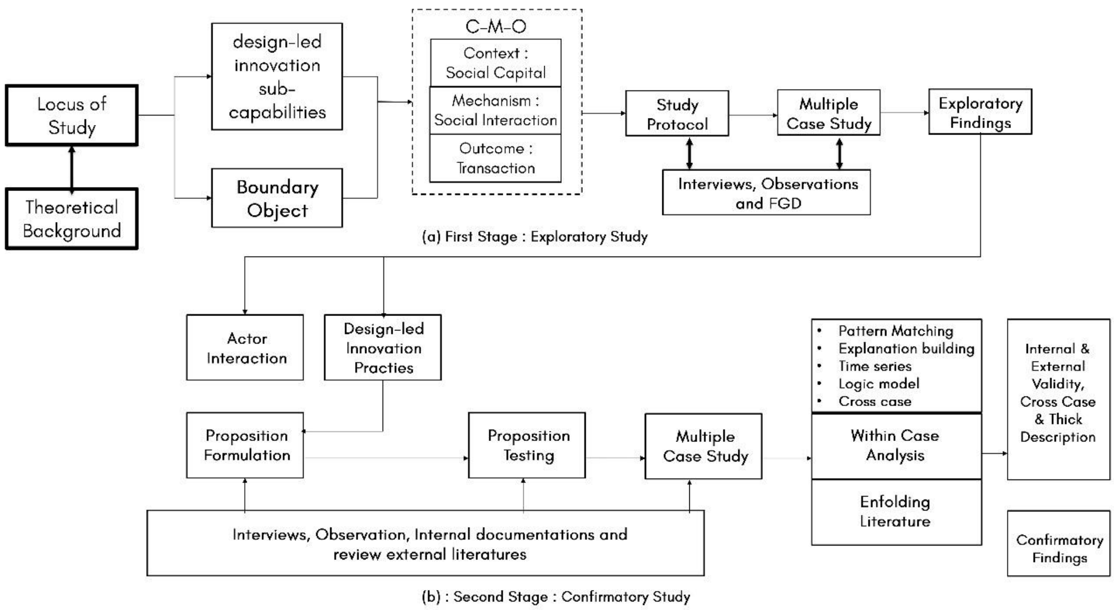

Figure 8. Research Framework

The First Stage: An Exploratory Study

This stage's case study protocol includes an instrument, a questionnaire, and generic guidelines to be followed during field research (Yin, 2009). We aim to gain a deeper understanding of an insights into the design-led innovation process and practices through protocol analysis, surveys, and semi-structured interviews. In addition, the protocol research will determine whether the questions asked during the interviews can be further interpreted as operational variables. The protocol study's questions will be based on a comprehensive literature review and a specific research question.

The semi-structured interviews were conducted using interview guidelines created throughout the data-gathering phase. Numerous investigators were used to assess study validity, increase trust in results via peer evaluations, and enable multiple observers to evaluate the case from various angles (Yin, 2009). Triangulation is a component of internal validity in qualitative research. To triangulate, each investigator on this project must collect qualitative data using the same procedure, including interviewing, observation, and probing.

Confirmatory Study in the Second Stage

The following data analysis compares the nine hypotheses to the exploratory results of a cross-case study. This study followed Eisenhardt's (1989) recommendation of "...examining the data in various diverse approaches" to avoid drawing hasty conclusions. The interviewers began the cross-case analysis by focusing on specific categories and characteristics to identify cross-case trends. As a result, specific categories resulted in patterns, whereas others did not. This is referred to as pattern matching. The pattern matching analysis was used to compare and develop the original identified pattern with the field finding pattern observed during the field study (Yin, 2009), to integrate theory into the research process, and to discover reliable patterns of causal relationships between independent and dependent variables by comparing initial propositions to the pattern observed characteristics case by case.

Eisenhardt (1989b) noted that after conducting a within-case analysis, the next step is to enfold the literature. Enclosing literature means comparing it to comparable or contradictory literature as part of internal validity to increase the generalizability of the construct definition. The confirmatory research considers exploratory data and nine assertions from the first stage to test the claims. Boundary objects and structures enable the interpretation of actor interactions during transactions and in the practices of design-led innovation.

According to Yin (2009), several instances were chosen to evaluate the applicability of current theories in settings where they have not been examined. All data acquired during the exploratory investigation were used to test the propositions and seek literal replication to corroborate and validate the research conclusions. The proposition guided and molded each case study's data gathering and analysis (pattern matching analysis). The comparison of many case studies is predicated on establishing and using a clear theoretical framework (within-case analysis). Consequently, analytic generalization is used, and identical findings from various examples are claimed to indicate the kind of replication (enfolding literature).

Four tests were used to assess the quality of this case study research: construct validity, internal validity, external validity, and reliability. This study uses a variety of sources of evidence and involves the examination of research results through key informants (Yin, 2009). Internal validity determines whether the theory, statement, or study findings are consistent with assuring the research's internal validity. External validity is critical at this level since several case studies have been used. Analytical generalization becomes critical at this stage. The replication logic approach is used in many case studies to ascertain the domain to which a study's conclusions can be applied. The purpose of dependability in this research is to reduce mistakes and biases by obtaining feedback from key informants or subject matter experts.

Triangulation is a data collection method that involves comparing and verifying the accuracy of data acquired via observations and interviews. To verify external validity, cross-case analysis and an extensive description were performed. Cross-case analysis is a method for evaluating and validating data and information gathered during field investigations. The study results were presented using cross-case analysis. It is usual for this procedure to overlap data collecting and data analysis (Eisenhardt, 1989b).

Additionally, the study's findings accompanied by detailed descriptions provide a thorough insight into the readers, including analysis and research interpretation while highlighting the research's strengths and limitations.

CONCLUSIONS

This conceptual study examined how boundary objects function as generative mechanisms supporting the micro-foundations of design-led innovation. Through a Critical Realist lens guided by Context-Mechanism-Outcome (CMO) logic, this paper proposes a set of theoretical propositions that link different boundary objects with sub-capabilities in the dynamic innovation process—namely sensing, seizing, and reconfiguring. While empirical validation is forthcoming, the conceptual framework developed here offers an integrative explanation of how shared artefacts may operate across internal and external boundaries to facilitate coordination, meaning-making, and adaptive capacity in design-driven settings.

Theoretical Implications

This study advances boundary object theory by moving beyond the notion of artifacts as static knowledge repositories and repositioning them as dynamic enablers of epistemic convergence, particularly in settings marked by ambiguity and divergent perspectives. This refines the understanding of boundary objects' role in shaping—not merely transferring—knowledge across functional and cultural divides.

Furthermore, by embedding these insights within a design-led innovation context, this research offers a novel articulation of how micro foundational mechanisms unfold in collaborative innovation processes. The application of Critical Realism and retroduction as methodological lenses underscores the value of uncovering latent structures that explain why and under what conditions design outcomes materialize, contributing to theory-building in design management and organizational innovation.

Practical Implications

For practitioners, the proposed framework offers a mechanism-oriented guide for intentionally leveraging boundary objects in innovation practices. This suggests that the success of such artifacts lies not only in their form or function, but also in their alignment with the context and capabilities of the teams that engage with them. Design managers, innovation leads, and interdisciplinary teams can use this insight to tailor artifact use—be it prototypes, maps, or templates—to meet the specific demands of their innovation phase.

LIMITATION & FURTHER RESEARCH

As a conceptual study, this paper is constrained by the lack of empirical validation. The proposed mechanisms and propositions, while theoretically grounded, require further testing through in-depth case studies or comparative analysis across organizational contexts. Additionally, the role of boundary objects may differ significantly across cultural and industry settings—factors factors that have not yet been explored in this framework.

Future research could build upon these insights by operationalizing the propositions in empirical studies and employing a Critical Realist approach to trace how mechanisms unfold under different contextual configurations. Longitudinal research may also reveal how the generative capacity of boundary objects evolves and influences sustained innovation outcomes. By extending this work into practice, scholars can refine and challenge the proposed mechanisms, thereby strengthening the bridge between theory and the dynamic realities of design-driven innovation.

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