Understanding Organizational Performance in Dynamic Environments: An Integrative Framework of Activity-System Maps and the NK Model

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ABSTRACT

There is a great need for business education to promote the understanding of how organizations as complex systems, composed of sets of interdependent activities, perform in dynamic or turbulent environments. However, there is a lack of appropriate tools to teach such dynamic and complex interdependencies by addressing the main challenges simultaneously—enhancing analytical, systems, and design thinking as well as avoiding cognitive overload. To address these challenges, we develop a framework that integrates the concept of activity-system maps and the NK model. We use two companies—IKEA and MUJI—to demonstrate the utility of the framework and illustrate the effects of environmental change on organizational performance and the patterns of resilience in organizations. Our integrative framework and demonstration offer visible experiment-based insights for teaching about complex organizations in business education.

Keywords: systems thinking; design thinking; activity-system maps; NK model; performance landscape

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Today's businesses face increasing demands: organizations must manage complex activities and processes, exploit new opportunities to achieve strategic positions, address emerging threats, and adapt quickly in dynamic environments (e.g., Ketchen Jr, Snow, & Street, 2004; Sheffi & Rice, 2005). Some scholars and business educators argue that business school students are not prepared for the increasingly complex and turbulent business environment (e.g., Bennis & O'Toole, 2005; Glen, Suciu, & Baughn, 2014). In response, prominent calls and efforts have been made in business education to adopt various pedagogical approaches to equip students with concepts, skills and tools for maneuvering in complex business environments (e.g., Atwater, Kannan, & Stephens, 2008; Glen et al., 2014; Hallinger & Wang, 2020; Mitchell, 2004; Salas, Wildman, & Piccolo, 2009; Waddock & Lozano, 2013). Particularly, business educators need to facilitate students' understanding of organizations as complex systems composed of various types of interdependent components (e.g., activities, policies, and resources) that interact with dynamic environments (Porter, 1996; Siggelkow, 2002).

However, there are mainly two challenges in teaching interlinked organization systems and learning how to achieve better organizational performance in dynamic or turbulent environments. First, to understand these complex and dynamic phenomena, a set of different cognitive skills is required: systems thinking and design thinking, as well as more traditional analytical thinking (Atwater et al., 2008; Glen et al., 2014). Business curricula still emphasize analytical thinking that focuses on independent parts rather than on the dynamic interdependencies of these parts (e, g., Atwater et al., 2008). In contrast, the opportunities to develop systems thinking and design thinking that involve holistic, dynamic, interactive, and exploratory approaches, have not been sufficiently provided in business education (Atwater et al., 2008; Glen et al., 2014). Second, without appropriate tools, the complexity of the phenomena in this topic cannot be processed by human cognition because of the limited cognitive load, or "the total amount of mental effort used in the working memory" (Angwin, Cummings, & Daellenbach, 2019: 528). Without appropriate tools, cognitive overload prevents students from understanding how interlinked organizations interact with dynamic environments to generate performance. We do not have effective tools to address these challenges simultaneously while teaching how complex organizations perform in dynamic environments.

To address the above challenges, we seek to integrate two pedagogical methods for teaching students better to understand complex organizations operating in dynamic environments: (a) the concept of activity-system maps (Porter, 1996) and (b) the computer simulation using the NK model (Kauffman, 1993; Kauffman & Levin, 1987). Activity-system maps, or representations of sets of discrete but interdependent activities in which competitive advantages reside (Porter, 1996), are commonly used in practice (Zott & Amit, 2010). Mostly using real company cases, an activity-system map serves as an abstraction of an organization and facilitates the discussion of the organization's strategy and operations, enabling questions such as "could changes in one activity eliminate the need to perform others?" (Porter, 1996: 72). The NK model, a mathematical model originally developed in the field of evolutionary biology (Kauffman, 1993), allows scholars to computationally construct interaction matrices and performance landscapes using two key parameters: the number of activity choices (N) and the number of interdependencies between each activity and the others (K).

Both approaches have strengths and weaknesses for studying the performance of complex organizations in dynamic environments. For example, a concise representation created in activity-system maps helps facilitate the discussion of an organization's strategy and operations. Teaching the theoretical principles of activity-system maps, however, does not provide insights explaining emerging nonlinear behaviors of complex systems. On the other hand, while researchers have applied the NK model to examine various research interests in strategic management and organization theory (e.g., Fang, Lee, & Schilling, 2010; Levinthal, 1997; Levinthal & Marino, 2015), the model is rarely discussed or applied as an instructional method to teach complex organization. This might be because the NK model can be too abstract for teaching when it is used alone without being connected to actual business contexts.

We argue that integrating these two pedagogical approaches—case studies with activity-system maps and subsequent computer simulation using the NK model—creates a new educational tool to understand how organizations perform in dynamic environments. These two approaches complement each other, offsetting the limitations of each used alone and offering an approach for cultivating their analytical, systems, and design thinking as well as avoiding the students' cognitive overload. To demonstrate how this framework operates, we apply it to illustrate how two companies—IKEA and MUJI—progressively adapt the complex relationships among their resources to achieve competitive advantages and respond to turbulent business environments. Our integrative framework offers visible experimental- and evidence-based insights into understanding organizational performance and resilience in dynamic or turbulent environments.

Our study contributes to business education literature by addressing the challenges for understanding complex organizations. First, we discuss the major challenges in teaching the performance of complex organizations in dynamic or turbulent environments and theoretically explains why the combination of activity-system maps with the NK model addresses these challenges. Second, we explain the process of translating the description of the strategy and operation of real companies into computer modeling and simulations using the NK model, thereby demonstrating how the integrative framework functions. We model two types of exploration strategies—a moderate and a customer-oriented one—to reflect the organizations' strategic development and examine how stable, turbulent, and disruptive environments influence the effectiveness of these strategies. The results of the case demonstration show that our integrative framework provides business students with new findings to learn, which may not be achieved without using our framework.

The remainder of this article is structured as follows: First, we present the theoretical background of cognitive mechanisms in relation to understanding an organization's complex systems and build their connections to activity-system maps and the NK model. Second, we present the step-by-step application of the integrative framework (see Figure 1). Third, we use the case studies of two companies to demonstrate the utility of the framework and display the results. Finally, we discuss the study implications and present our conclusions.

Insert Figure 1 about here

THEORETICAL BACKGROUND

Cognitive Mechanisms for Understanding Complex Organizations

Scholars conceptualize organizations as structural configurations (Miller, 1982), such as systems composed of various types of interdependent components, including activities, policies, and resources) (Siggelkow, 2002) or sets of discrete but interdependent activities that derive competitive advantages (Porter, 1985, 1996). In this sense, the way of representing an organization as a set of interdependent parts can be analogous to the perspectives of complex adaptive systems (Anderson, 1999; Siggelkow & Levinthal, 2003; Simon, 1962), described as "one[s] made up of a large number of parts that interact in a nonsimple way" (Simon, 1962, p. 468). Business schools have emphasized a set of cognitive skills essential to learning complex organizations through various pedagogical approaches. We posit that at least three different cognitive skills are required to learn how to manage complex organizations in dynamic environments: Analytical thinking, systems thinking, and design thinking.

Analytical thinking, the cognitive skill that breaks a whole into its components and analyzing parts in isolation, is what business curricula have traditionally been emphasizing (e.g., Atwater et al., 2008). This skill might help explain what to include and not include among many activity choices to increase organizational performance. However, analytical techniques for business education with a trenchant focus, if overemphasis, may lead to the paralysis of analysis and cannot cope with blurring real-world conditions (Atwater et al., 2008; Gharajedaghi, 2006; Waddock & Lozano, 2013). Besides, two main factors of organizational phenomena in dynamic environments—time and complex interactions—continue to challenge the effectiveness of analytically based teaching approaches to promoting students' understanding of complex organizations in turbulent environments (e.g., Atwater et al., 2008; Forrester, 1971). As time unfolds, interdependencies of parts can amplify small changes and manifest counterintuitive behaviors because of dynamic and nonlinear feedback effects (Atwater et al., 2008; Kozlowski & Klein, 2000). Therefore, while analytical thinking has strengths such that it enhances the detailed understanding of independent parts, this way of thinking is constrained to shed insight on projecting future states of complex organizations in dynamic environments.

To understand the behavior of complex interdependencies evolving over time, researchers and educators advocate a new set of cognitive skills, including systems thinking and design thinking. The researchers asserted that systems thinking, defined as a discipline for seeing wholes and a framework for seeing interrelationships rather than things (Senge, 1990), enables individuals to address the complex interrelationships of components and patterns of change rather than static snapshots and to understand the larger context within which a system operates (e.g., Atwater et al., 2008; Gharajedaghi, 2006; Senge, 1990). Systems thinking encompasses multiple complementary elements: for example, synthetic thinking, dynamic thinking, and closed loop thinking (Atwater et al., 2008). Gharajedaghi (2006) deemed systems thinking to be the art of simplifying complexity, enabling practitioners to manage interdependent choices. Atwater et al. (2008) stressed that business leaders need a holistic perspective of systems thinking to manage ever-increasing business challenges, and systems thinking would benefit business curricula in ways such as strategy and operations management.

Prominent research has endorsed design thinking as an approach for dealing with messy, complex, and ill-defined problems (e.g., the strategy development process of an organization in our study) (e.g., Dunne & Martin, 2006; Glen et al., 2014; Kurtmollaiev, Pedersen, Fjuk, & Kvale, 2018). The essence of design thinking is an iteratively exploratory and human-centered process that involves observing, visualizing, experimenting, making model prototypes, and gathering feedback, and is a general cognitive process that facilitates adaptive reasoning (Glen et al., 2014). Business schools have embodied the concept of design thinking in their curricula (e.g., strategic management and entrepreneurship), and the design practice is spreading into a wide range of activities beyond the product design area (e.g., Glen et al., 2014; Kurtmollaiev et al., 2018). Design thinking is a useful cognitive skill in understanding complex organization in dynamic environments because nonlinear feedback effects are not easily predicable using analytical thinking. Active experimentation with appropriate tools, where sketches, prototypes, and simulations can be used to aid in sense making how the whole organizational system with interdependent parts evolves over time (Glen et al., 2014).

While all of the analytical, systems, and design thinking should be developed to understand organizational performance in dynamic environments, the demand to discern increasing interconnections in any organization—let alone adding needs to project the future states of such relationships—can exceed the cognitive load of human beings (e.g., Kast & Rosenzweig, 1972). For example, although systems thinking advocates thinking dynamically and thinking in terms of a feedback loop (Atwater & Pitman, 2006), it is a daunting task to cognitively understand the evolution of interlinked organizations that respond to turbulent changes (Bhamra, Dani, & Burnard, 2011), have reciprocal influence over time (Cronin, Weingart, & Todorova, 2011), and exhibit unpredictable and nonlinear behaviors (Anderson, 1999). Indeed, studies have shown that the human mind is not adapted to truly interpreting the behavior of complex systems without the assistance of tools (e.g., Forrester, 1971). Therefore, we need appropriate tools to overcome the cognitive overload that prevents students from understanding how interlinked organizations interact with dynamic environments to generate performance.

Besides, learning through active experimentation, visualization, and exploration, which are essential in design thinking, may not be possible in real organizations. Particularly, it is difficult to visualize the dynamic and nonlinear feedback effects in the interdependent systems. Therefore, without using effective aiding tools, understanding the behavior and performance of complex organizations under dynamic or turbulent environments, by activating all of the analytical, systems, and design thinking, is not possible. In this regard, one paradigm of instructional design is to integrate the tools of computational modeling and simulations to directly examine the nonlinear behaviors of complex systems evolving over time and advance the understanding of emerging system-level phenomena (Kozlowski, Chao, Grand, Braun, & Kuljanin, 2013). Specific tools such as NK modeling (Kauffman, 1993; Kauffman & Levin, 1987) have been developed to facilitate the understanding of how interdependent parts of a system interact. For a detailed comparison of tools, see Davis, Eisenhardt, and Bingham (2007).

Activity-System Maps

The activity-system maps developed by Porter (1996), are the visual representation of how an organization's strategic position is contained in a set of tailored business activities designed to deliver it. This mapping tool reflects the idea that the essence of strategy or strategic positioning is to choose activities that are different from those of rivals. Competitive advantage grows out of the entire system of interdependent activities that rivals cannot easily imitate or replicate. Once an organization clearly identifies its strategic position, a number of higher-order strategic themes (or core elements) can be determined and reinforced through clusters of interlinked and interdependent activities (or elaborating elements). The activities interact with and are dependent on one another, and they achieve a high consistency of fit if changing any single activity leads to a decline in performance (Porter & Siggelkow, 2008).

Activity-system maps are frequently taught in business education to display rich snapshots of case companies (e.g., Jacobs, Chase, & Lummus, 2014). Generally speaking, graphical mapping helps people make sense of complex ideas by providing a way to structure and simplify the complexity (Angwin et al., 2019; Fiol & Huff, 1992). Indeed, a concise representation created in activity-system maps helps facilitate the discussion of an organization's strategy and operations. However, teaching the theoretical principles of activity-system maps does not provide insights into the nonlinear behaviors of complex systems. For example, to effectively construct activity-system maps of any organization, Porter (1996) created a set of guiding questions: "Is each activity consistent overall positioning?"; "Are there ways to strengthen how activities and groups of activities reinforce one another?"; and "Could changes in one activity eliminate the need to perform others?" In this way, the visual representation of business activities illustrated in activity-system maps helps facilitate the discussion of an organization's strategy and operations. However, to fully answer Porter's (1996) questions for dealing with such complex interdependency, use of activity-system maps alone may not be sufficient.

As discussed, applying only analytical thinking is not enough and a set of cognitive skills—such as systems thinking and design thinking—and tools are required to understand how to select and configure business activities to achieve better organizational performance. Without an adequate approach promoting new cognitive skills and tools that focus on complex organizations in dynamic environments, an understanding of the consequences of interactions in activity-system maps will remain a challenge in business education.

NK Model

The NK model is well suited for investigating interdependencies in a complex system (Kauffman, 1993; Ganco & Agarwal, 2009) and is appropriate for creating theories of management and organizations (Davis et al., 2007; Harrison, Lin, Carroll, & Carley, 2007). Using the number of activity choices (N), the number of activity interdependencies (K), and the performance landscapes, the NK model allows scholars to construct a conceptualization of a complex system and systematically simulate and analyze various business scenarios. Improving a company's performance through the processes of configuring interrelated activities is analogous to identifying a high peak on a rugged performance landscape through a sequential search (e.g., Levinthal, 1997; Siggelkow, 2002).

Organizational researchers have applied the NK model and used computer simulations to examine various interactions in organizations and business contexts: for example, the development of effective knowledge-search processes through the design of organizational systems, organizational adaptation, and the relationship between the interaction patterns of an organization's activities and its resultant performance (e.g., Fang et al., 2010; Levinthal & Marino, 2015; Marengo & Pasquali, 2012). The NK model can provide visual and traceable evidence of the nonlinear development of complex systems using the following components and the mechanism.

Interaction matrix. An interaction matrix is a representation of the interdependencies among a set of discrete organizational activities or choices. On the basis of the topology of an activity-system map of any organization, one can construct the respective interaction matrix, determining the numbers of activities (N) and activity interdependencies (K) and computing the value of K by dividing the number of off-diagonal interaction effects by N (Rivkin & Siggelkow, 2007). If K equals 0, the contribution of each activity depends only on the activity itself, which means that all activities are independent; if K equals N – 1, the contribution of each activity depends on how the activity itself and all other activities are resolved, meaning that all activities are fully interconnected.

Performance landscapes. A performance landscape is a mapping of any possible vector of N organization activity choices $\mathbf{a} = < a_1, a_2, \ldots, a_n >$ to a performance value $\mathbf{P_a}$. Performance landscapes can develop in different shapes by exhibiting various numbers of peaks in a multidimensional search space. Peaks with different heights represent a certain level of consistency among a set of activity choices, and most are local peaks (e.g., Levinthal, 1997).

Generally, the larger the value of N, the more widely the peaks are distributed throughout the search space. The denser the interdependence of the activities (i.e., the larger the value of K), the more rugged the performance landscape becomes—in other words, the more the local peaks in a landscape) (Levinthal, 1997). As a result, greater interdependencies among activities lead to a more rugged landscape with a larger number of local peaks; this makes searching effectively more challenging and decreases the likelihood of achieving a global peak, which has the highest performance value (Rivkin & Siggelkow, 2003). Therefore, an organization needs a broader exploration strategy to achieve better performance and avoid the trap of a sticking point—a configuration of a chosen activity from which it will not improve (Rivkin & Siggelkow, 2003).

Exploration strategy. The variance and height of the peaks in a performance landscape reflect the performance (or fitness) values of the associated interdependency of the organizational activities (Levinthal, 1997). Thus, organizations search for better ideas and solutions and improve performance by changing the directions of their activities. Low exploration strategies (Rivkin & Siggelkow, 2007) rely solely on local search (Levinthal, 1997) that represents an incremental move, typically as a single step within its immediate neighborhood in the performance landscape. In a performance landscape, an organization starts at random choice configuration **a**. In each period, an organization evaluates a randomly chosen alternative **a**' that differs from **a** in terms of one activity choice and adopts **a**' only if it yields higher performance. As an organization only explores an alternative in the neighborhood of its current configuration, this process of exploration results in "hill climbing" and typically ends in a relatively low-performing local peak (Rivkin & Siggelkow, 2007).

Moderate exploration strategies represent searching for innovative solutions. They combine local search with distance search or long jumps (Kauffman, 1993) that represent moving beyond the immediate neighborhood by changing multiple directions at the same time (Ganco et al., 2020; Wall, 2016). In a performance landscape, an organization considers a randomly chosen and distant alternative **a**' that differs from **a** in terms of as many N activity choices and adopts **a**' only if it yields a higher performance. For a detailed review of organizational search in rugged performance landscapes, see Baumann et al. (2019).

One of the main strengths of computational modeling (i.e., the NK model in the study) is that it allows students to create a theoretically based model and systematically vary a great number of built-in parameters and assumptions running under different business scenarios, which aid the students in conceiving of interrelationships of organizations, promoting systems and design thinking through conducting experiential and exploratory simulations and visibly examining how complex organizations behave as a whole. Business school curricula, nevertheless, fall short of sufficiently educating students on the benefits of computational tools and, in particular, rarely apply the NK model as an instructional method by linking it to actual business contexts. As an educational tool, the NK model advocates systems thinking and design thinking to understand complex organizations (e.g., through experimenting simulations and visibly examining how complex organizations behave). In addition, business students can benefit greatly from the accumulated knowledge of NK model research to understand the characteristics of interdependent organizational systems. However, the NK model can be too abstract for teaching when it is used alone without being connected to real business contexts.

FOUR-STEP INTEGRATIVE FRAMEWORK

Combining Activity-System Maps and the NK Model

We propose an integrative framework of combining two pedagogical approaches that both address interdependence in organizations but offer different advantages benefiting both teaching and learning. By translating real company cases into the maps of the interrelationships among key activities, activity-system maps reduce the level of complexity in real organizations and clarify the interdependencies among key activities. Subsequently, the computer simulation using the NK model iteratively and experimentally explores how performance of the organization with the interdependencies specified by the activity-system maps evolve over time in dynamic or turbulent environments (Davis et al., 2007). The integrative framework overcomes the constraint of cognitive load and enables business students to practice essential skills such as analytical, systems, and design thinking to understand complex organizations as a whole, and to engage in the discussion of how to achieve better organizational performance, and continue to refine the formulation of activity-system maps of case companies. The following is the four-step integrative framework of activity-system maps and the NK model.

Step 1: Build Activity-System Maps

Porter (1996) viewed competitive advantages as the purposeful choosing of a different configuration of activities to deliver greater value to customers and used an activity-system map to illustrate how the activities of a particular company (e.g., IKEA) were linked. In such interlinked systems (e.g., organizations), a large number of parts leads to a large number of possible combinations of activity choices. Moreover, interdependencies among the parts suggest that different combinations will produce varying results in terms of their performance or viability (e.g., Siggelkow, 2001). To achieve strategic positions and improve performance, organizations must explore multiple configurations of activity choices, understand the trade-offs among the interconnected activities and identify the ideal set of configurations to execute (Siggelkow, 2002).

Step 2: Construct NK Model

We assume that a company system, represented as an activity-system map, is composed of N interdependent strategic activities denoted by a vector of <a_1, a_2, …, a_N>. Based on the topology of its activity-system map, we can construct the interaction matrix (e.g., the determination of N and K) and create the performance landscapes as follows:

$$P(a_1, a_2, \ldots, a_N) = \sum_{i=1}^{N} C_i(a_1, a_2, \ldots, a_N) \; / \; N$$

Following the methods used in previous research (e.g., Levinthal & Workiewicz, 2018; Siggelkow & Levinthal, 2003; Siggelkow & Rivkin, 2006), each activity a_i takes one of two states: 0 or 1. For example, a_1 may represent the managerial decision to reinforce the activity of self-service by customers ($a_1 = 1$) or diminish that activity ($a_1 = 0$). The company then has 2^N possible configurations of activity choices. The contribution C_i of each individual activity a_i is affected by both the state of the activity itself (0 or 1) and the states of other activities a_{-i}, depending on the interaction matrix. The values of C_i are determined by drawing randomly from a uniform distribution over the unit interval, i.e., C_i (a_i, a_{-i}) ~ u [0, 1]. The performance P (**a**) of a given set of activity choices **a** is given by the average of the N contributions.

An organization has an initial vector $\mathbf{a_i}$ <a_1, a_2, …., a_N> with an initial performance $\mathbf{P_i}$. In each period, the company changes its choice configuration according to its exploration strategy (i.e., the strategy to explore the business opportunities; e.g., a low or moderate exploration) to generate a new vector **a'** with new performance **P'**. If **P'** is greater than $\mathbf{P_i}$, the company would move to the new set of the choice configuration **a'**. If not, it would maintain the status-quo. In this study, for each type of exploration strategy operating in different business scenarios, we ran 1,000 simulations and 500 periods per condition, as the results reveal enough similarity to indicate that no additional runs would be productive. We recorded the average of the 1,000 simulated performance values.

Step 3: Conduct Exploratory Simulations

One of the advantages of computational modeling and exploratory simulations is that they allow business students to create theoretical models and systematically vary a great number of built-in parameters operating under different scenarios, which is challenging using traditional approaches (Davis et al., 2007). Moreover, a virtual setting provides a safe environment for making modifications without creating risks and sensitivities for individuals, teams, and organizations.

In most prior studies that use the NK model, researchers treated the performance landscape as either stable (e.g., Siggelkow & Rivkin, 2006) or turbulent to a certain degree (e.g., Levinthal, 1997; Li, Chen, & Ying, 2019; Siggelkow & Rivkin, 2005). In other words, organizations are deemed as operating in *stable* environments on the same performance landscape for their entire life histories. We argue that while some organizations operate in a relatively stable environment (e.g., food industry), business environments for other organizations are often typified by turbulence (e.g., fast-moving consumer goods industry and high-technology industry), with frequent and unpredictable market or technological changes. In other words, an organization enjoys only temporary competitive advantage as its values delivered to customers may suddenly become obsolete. Therefore, we expand the application of the NK model and propose exploratory simulations to study the effects of turbulent environments and the patterns of organization resilience after a disruptive event.

We followed the methods of Siggelkow and Rivkin's (2005) study to model *turbulent* environments. In turbulent environments, the performance landscape undergoes turbulence at periodic intervals, meaning that in every Δ period, each contribution value C_i is replaced by (1 –

τ) × C_i + τ × *u*, where τ is a significant level of turbulence, and *u* is a new draw from a uniform distribution *u* [0, 1]. To clearly capture the effects of turbulent settings, following Siggelkow and Rivkin's (2005) study, we also set the performance landscape to be perturbed every fifth period ($\Delta = 5$), with a correlation between landscapes of $\tau = 0.2$.

To model a disruptive event, we fluctuated the performance landscape (i.e., we re-specified the payoff structure of the N-vector array that characterizes an organization) to reflect the effect of business shock at the halfway point in the simulation (i.e., 250 periods in our study). Therefore, the performance values of a given activity configuration may not remain the same, resulting in either an increase or decrease in a new set of activities in the performance landscape.

Using different paths of exploration strategy, we measured the effects of business shocks and the patterns of the organization's resilience in terms of its initial impact and the time needed to complete four levels of recovery (i.e., 25%, 50%, 75%, and 100% of the level of organizational performance before the business shock).

Step 4: Connect the Feedback Loop

As business students learn and visualize the simulation results in Step 3, the evidence may suggest, for example, that shifting to a different state of activity choices or to a different configuration of activity relationships can create an increased competitive advantage or rapidly drive more organization resilience over time. Thus, based on the evidence rather than on conjecture, business students can effectively debate which core and supporting activities are included and how their associated relationships interplay to produce an optimized activity-system map, as well as to achieve the company's strategic fit within business environments. Through connecting the feedback loop, the discussion of how to achieve competitive performance becomes progressive, and the formulation of activity-system maps becomes refined.

With the integrative approach, students can impart a set of cognitive skills—a rigorous analysis of case companies—to build their activity-system maps and NK models accordingly. They can also develop systems thinking that involves conceiving the interdependent activity choices of complex organizations. Furthermore, they can develop design thinking through an iterative and experimental process to reconfigure activity-system maps based on computer simulations. This is necessary to bring their learning skills closer to the real world.

DEMONSTRATION: CASE STUDIES OF IKEA AND MUJI

In our demonstration, we used two companies as examples (IKEA and MUJI) for three reasons. First, the activity-system maps of IKEA and MUJI are publicly available and are ready for use (Porter, 1996; The Porter Prize, 2007). Second, IKEA and MUJI possess distinct business philosophies that define their different strategies for achieving organizational performance. Third, both companies reside in the fast-moving consumer goods industry, which is characterized by changing business environments. In our study, which was built on IKEA's and MUJI's available activity-system maps, we reflected on their strategy developments, and we illustrated the different path that each company followed to achieve performance. We modeled three types of business environments (i.e., stable, turbulent, and disruptive) to simulate how each company responded to changing environments.

One should note that the purpose of this case study is not to predict either company's performance or to discuss which company is superior. Rather, this case study serves to demonstrate our proposed framework's utility. Thus, the simulation results do not accurately reflect reality.

IKEA

Founded in Sweden in 1943, IKEA has become a well-known home-furnishing brand. In

2018, IKEA had 422 stores in more than 50 markets, generating about 38.8 billion euros in sales (IKEA Group, 2018). IKEA's vision is "to create a better everyday life for many people" (IKEA Group, 2017: 10), and it claims that its strategy is "to offer a wide range of well-designed, functional home furnishing products at prices so low that as many people as possible will be able to afford them" (IKEA Group, 2018). "Doing it a different way," or encouraging people to be innovative, is rooted in IKEA's culture (IKEA Group, 2017). For example, one of IKEA's concepts is to offer a self-service system to offer low prices. IKEA customers have to self-scan items; find products in the store based on clear, in-store displays; self-transport their products; and self-assemble their furniture. Namely, IKEA serves customers who are happy to trade off service for low cost (Porter, 1996).

MUJI

We used MUJI—a Japanese retail brand that sells household goods, apparel, and food products—for comparison with IKEA. MUJI was launched in 1980 as a proprietary brand with 40 items (Ryohin Keikaku Co., Ltd., 2019). In fiscal 2018, MUJI expanded to more than 900 stores in 28 markets, carrying more than 7,000 items with revenue of about 410 billion Japanese yen (Ryohin Keikaku Co., Ltd., 2018). Aiming to serve the lifestyles of the people who use MUJI products, MUJI's overall strategy is to serve the purpose of its customers who wish to live a simple and beautiful life in the basic areas of household goods, clothing, and food (Ryohin Keikaku Co., Ltd., 2018). Like many other Japanese firms, MUJI orients its business model to its customers. For example, according to MUJI, one of its corporate philosophies is to "identify and deliver MUJI value and appeal from the perspective of the people who use our products." The first priority of its code of conduct is to "quickly and carefully respond to customer needs" (Ryohin Keikaku Co., Ltd., 2018: 2). In contrast to IKEA, MUJI does not trade off its customer service for cost purposes. MUJI craves alternatives, such as carrying no logos on products, focusing only on the primary product features or functions, and avoiding excessive packaging (The Porter Prize, 2007).

SIMULATION PROCEDURES AND RESULTS

We followed the proposed four-step framework to display the results of the two companies. First, we built the activity-system maps, respectively. Second, we constructed NK models, including interaction matrices, performance landscapes, and exploration strategies. Third, we simulated the development of organizational performance under three business environments. Fourth, we reran the simulations by modifying the activity-system maps to illustrate the example of performing the feedback loop.

Activity-System Maps of IKEA and MUJI

Porter (1996) showed IKEA's activity-system map as a fundamental element of its competitive strength: four strategic themes (shown in different colors) are centrally implemented through clusters of interlinked activities (see Figure 2a). The map illustrated that IKEA's activity choices regarding modular product design, customer self-service, low manufacturing cost, and associated activities are mutually reinforcing (Baumann et al., 2019). The Porter Prize's (2007) activity-system map for MUJI showed three strategic themes (shown in different colors) as being central, along with the interplay of 15 activities (see Figure 2b).

Insert Figure 2 about here

NK Model: Interaction Matrices

Figure 3 shows the respective interaction matrices of IKEA and MUJI built according to their activity-system maps.

Insert Figure 3 about here

NK Model: Performance Landscapes

In creating performance landscapes, we highlighted the roles of the higher-order strategic activities (or themes) by placeing a higher weight (0.6, an arbitrary value) on central, higher-order activities than on the rest of the clusters of interlinked activities (0.4). With regard to the shapes of the performance landscapes, the average number of local peaks was approximately 350, and the average maximum value was 0.76 for IKEA (N = 20; K = 3.3), whereas the average number of local peaks was approximately 170, and the average maximum value was 0.75 for MUJI (N = 18; K = 2.9). The average values of the local peaks were 0.23 for IKEA and 0.25 for MUJI. The results aligned with Levinthal's (1997) findings that the larger K created more rugged performance landscapes with more local peaks, implying that it was more difficult to search for the optimum performance.

NK Model: Exploration Strategies

We examined three types of exploration strategies for the companies: (a) low exploration, (b) moderate exploration, and (c) customer-oriented exploration. As discussed above, whereas IKEA is deeply rooted in an innovative company culture that emphasizes "doing it a different way" (IKEA Group, 2017), MUJI places its customers as the primary concern (Ryohin Keikaku Co., Ltd., 2018). Hence, we modeled IKEA and MUJI, which opt, respectively, for moderate exploration and customer-oriented exploration. In both cases, we used low exploration as the control condition.

Low exploration. Low exploration as a control condition was operationalized as the changes of organizational activities based on a local search only. For example, for MUJI (N =

18), MUJI at <000000 000000 000000> may evaluate an alternative <000000 000000 000001>. MUJI could continue to do so in the rounds of time until it finds no superior alternatives.

Moderate exploration. Moderate exploration was defined in this study as moderate-level innovation-oriented firm behavior and was operationalized as the changes in organizational activities based on the combination of a local search and long jumps. In our model, we assumed that a 10% likelihood (an arbitrary value) of moderate exploration enabled IKEA to move beyond the immediate neighborhood and to make long jumps across the performance landscape by changing multiple activity states at the same time. For example, for IKEA (N = 20), IKEA at <00000 00000 00000 00000> may evaluate the alternative <11111 11111 11111 11111>, which is a long jump across IKEA's performance landscape.

Customer-oriented exploration. Customer-oriented exploration was defined in this study as changes in organizational activities based on the limited information available about the customer choices associated with the shape of the performance landscape. In each period, MUJI calibrated the current configuration to the ideal configuration according to the customer choices to identify the gaps (i.e., how many activity choices were different). In addition, it considered a randomly chosen alternative **a**' that differs from **a** in terms of having the same number of gaps. In practice, a firm can conduct focus group workshops, echo the voice of the customer, solicit feedback from customers, or analyze the segmentation of the market thoroughly to understand the ideal customer demands (i.e., the ideal configuration of choices), then gradually respond to the customers' needs by closing the gaps.

Assuming that the ideal configuration of the customer choices was <111111 000000 000000> (i.e., the global peak in the performance landscape of MUJI), MUJI (N = 18) at <00000 00000 00000 00000> may calibrate its current configuration and identify the number of gaps (6).

In addition, it may consider a randomly chosen and distant alternative that has the same number of differences (e.g., <111100 100000 100000>). Then, it may move to the alternative if it can yield a higher performance.

Exploratory Simulations Under Different Business Environments

Performance in stable environments. Following Rivkin and Siggelkow's (2007) study, we showed the average difference in cumulative performance between different paths of exploration strategies (see Figure 4). For IKEA (see Figure 4a), in the early periods, using a low exploration strategy outperformed a moderate one, resulting in a decreasing cumulative performance until about period 10. Afterward, with a glimpse of bumpy performance, the broader moderate exploration began to pay off, leading to a higher performance and a higher cumulative performance. MUJI (see Figure 4b) demonstrated three phases of performance as Rivkin and Siggelkow (2007) proposed. In the early periods, customer-oriented exploration outperformed low exploration, leading to an increasing cumulative performance advantage until period 10. Starting from that point, low exploration outperformed customer-oriented exploration until about period 100, causing favorable cumulative performance for low exploration. After around period 100, the broader search of customer-oriented exploration started to pay off, leading to a higher performance and a widening higher cumulative performance in the longer term.

Insert Figures 4 about here

Performance in turbulent environments. Figure 5 shows the comparison of IKEA's performance between stable and turbulent environments. Whereas IKEA's moderate exploration gradually increased its performance in every period in stable environments, in turbulent environments, the growth of IKEA performance had both upward and downward trends and eventually reached a higher performance. Rather than falling in the sticking-point trap (i.e., continue hill climbing to a local peak) in stable environments, IKEA had a chance to explore other local optimal points in turbulent environments. As shown in the insert in Figure 5, during a certain period of turbulence, IKEA can even climb down the current hill (i.e., by accepting the lower-performance position due to the turbulence) yet climb up another hill to explore other optimal positions.

However, the effect of turbulent environments on MUJI's performance was not distinct (see Figure 6). As argued, MUJI conducted customer-oriented exploration: in every period, MUJI calibrated the current configuration toward the ideal configuration and altered the organizational activities. The continuous reorientation of the internal configurations offset the effect of turbulent environments, suggesting that the speedy adjustment of organizational performance based on customer needs can cope with turbulent settings.

Insert Figures 5 and 6 about here

Performance that endures business shocks and resilience. Figure 7 shows the comparison of different levels of performance recovery. For IKEA, in a low exploration scenario, the initial effect (Sheffi & Rice, 2005)—calculated by the discrepancy between the performance value before the shock and the lowest performance value after the shock, divided by the value before the shock—was about 25.3%, whereas the effect was 24.4% in a moderate exploration scenario (see Figure 7a). For MUJI, compared with the initial effect (20.9%) in a low exploration scenario, the effect of a customer-oriented scenario was 22.7% (see Figure 7b). MUJI's activity system helped to buffer the business shock, suffering from a smaller initial effect compared with IKEA.

The recovery time (Sheffi & Rice, 2005) is the time it takes for an organization to overcome the disruption and to return to its normal state of performance. For IKEA's low exploration strategy, it took less time to recover fully at around period 92. With the moderate exploration strategy, it took a similar number of periods (around 35 periods) to recover to the 75% performance level. However, it took much longer to reach the 100% performance level before the shock occurred (see Figure 7a). For MUJI's low exploration strategy, it took around 76 periods to recover to the level of the performance before the shock occurred. For the customer-oriented exploration strategy, it took a similar number of periods (around 23 periods) to recover to the 50% performance level. However, it took quite a bit of time to recover to the higher performance level (see Figure 7b).

Insert Figure 7 about here

Feedback Loop Through Modifying Activity-System Maps

To illustrate the example of performing the feedback loop through modifying activity-system maps, we reran the simulations by changing the number of activities (i.e., N = 20 in IKEA; N = 18 in MUJI) and their interaction matrix. In this step, students can build their understanding of how different linkages of activities impact organizational performance once critical activities are identified. For example, one scenario can be that all activities are fully interconnected (i.e., K = 19 in IKEA; K = 17 in MUJI). As a result, greater interdependencies among activities decrease the likelihood of achieving the highest performance value unless more frequent exploration (i.e., long jumps) is deployed. Another scenario is that the clusters of independent activities connect to higher-order independent activities only, generating a lower K value (e.g., K = 1.6 in IKEA; K = 1.7 in MUJI). Figure 8 shows the performance development based on different levels of interaction matrices. There might not be a single best activity-system map that maximizes performance at any type of environment. Therefore, by visualizing the simulation results and rounds of discussion among students based on the results, the students can progressively refine activity-system maps to reach some conclusions about their modified activity-system maps.

Insert Figure 8 about here

Overall, our study showed that the performance advantage of both moderate and customer-oriented strategies takes time to realize compared with low exploration strategies in stable environments. Moreover, the results showed that turbulent environments help IKEA to avoid the trap of reaching a sticking point quickly. That is, encountering business turbulence allowed IKEA to step back and to reach a lower position of performance. Still, the company had a high likelihood of climbing to other optimal peaks considering that its performance landscape has approximately 350 local peaks (see Figure 5). It was also shown that MUJI's speedy adaption of its configuration toward customers' needs proved to offset the effect of turbulence. This suggests that the speedy adjustment of organizational performance based on customer needs can cope with turbulent settings.

We further extended the NK model's application to investigate the effect of business shocks and the patterns of organization resilience. We found that the effect of business shocks depends on the pattern of activity systems. For example, MUJI's less-coupled activity system helps to buffer business shock compared with IKEA's system (e.g., the initial effect of 22.7% for MUJI vs. 24.4% for IKEA). For different paths of exploration in the search for recovery, a low-exploration strategy leads to a relatively fast recovery from shock to a company's original performance level, whereas with both moderate and customer-oriented explorations, it takes much longer to recover from the initial shock.

DISCUSSION

We developed an integrative framework that combines activity-system maps and computer simulations with the NK model and used two company examples to demonstrate its utility. The case examples allow us to visually understand how the differences in the degree of interdependence, as well as the strategic focus, influence organizational performance in dynamically changing environments. Specifically, examining IKEA's and MUJI's activity-system maps enables us to visually understand how these two companies differ in terms of their strategies (i.e., innovative versus customer oriented) and how their activities are interrelated and interdependent to achieve such strategies. However, the way in which these two companies' performance evolves over time and how various environments (e.g., stable, turbulent, and disruptive) influence it are hardly predictable using activity-system maps alone. Subsequent computer simulations, which translate the activity-system maps to the NK model, visually and experimentally show the performance of IKEA and MUJI evolving over time in different environmental scenarios.

Through iterative, comparative, and experimental approaches, we can apply the research findings from the NK model studies to understand and make sense of what will happen to such companies as IKEA and MUJI in dynamic environments. For example, we can see that neither IKEA nor MUJI can easily find a global peak that maximizes performance in real business situations. We can also see that increasing interdependencies between activities within an organization can increase the number of local peaks in a performance landscape. This makes it difficult to find the global peak without the appropriate degree of long jumps or exploratory strategies. We can furthermore see that low exploration strategies that rely solely on a local search can easily end up with the local optimum. In addition, different types of environments influence these relationships in such a way that turbulent environments can allow organizations to avoid the trap of quickly reaching a sticking point. Instead, they can find other local peaks, or the global peak.

In actual business education, students can discuss a company's strategy and generate several versions of activity-system maps with different N and K values. Then, they can run simulations under different environmental scenarios and continue to fine tune them. Through the four-step framework with the feedback loop, students can activate systems thinking in understanding why and how non-linear changes happen in organizational performance, as well as why and how low exploration strategies are likely to lead to the local optimum. Students can also activate design thinking in fine-tuning activity-system maps while repeating and iterating computer simulations using various scenarios. Therefore, our results offered business educators and students traceable experiment-based insights into understanding complex organizations.

Theoretical Contributions

Our study contributes to the business education literature by identifying the challenges with teaching the performance of complex organizations in dynamic or turbulent environments and by showing that combining two pedagogical approaches mutually reinforces the strengths of each method and offsets their weaknesses to address the major challenges simultaneously. Specifically, the representation of activity-system maps provides students with snapshots of case companies and facilitates an analytical discussion about how to achieve competitive organizational performance. The computer simulations using the NK model stimulate students' systems thinking through enabling them to make interdependent decisions as well as examine how complex organizations behave to achieve organizational performance. The sequential combination of the mapping tool (i.e., activity-systems maps) and the computer simulation of mathematical models (i.e., the NK model) help with avoiding cognitive overload for understanding complex phenomena by clarifying their interdependencies, aiding in non-linear computation, and visualizing the results dynamically. Moreover, our integrative framework reflects the essence of design thinking as an exploratory process that involves experiential experimenting, visualizing, and a feedback loop (Glen et al., 2014).

Our study also showed the importance and usefulness of translating the description of case studies into computer modeling and simulations for business education. In other words, bridging the mapping of concrete managerial practices (i.e., activity-system maps for describing the competitive advantages of case companies) to more abstract mathematical and computational models (i.e., the application of the NK model and performance landscapes) can facilitate teaching effectiveness by connecting concrete examples and highly abstract mechanisms and principles. Indeed, little research has examined which management contexts are effectively advanced using simulation-based training, as well as the relative utility of simulation for different business topics (Salas et al., 2009). Business school faculty in one study indicated that strategy and operation management have the strongest ties to systems thinking (Atwater et al., 2008). We echo these calls by linking the strategic development of real companies to the NK model. In this way, deeper insights can be gained by bringing computer modeling closer to actual business contexts and conducting experiential and exploratory simulations according to practical business scenarios.

Implications for Practice

The effectiveness of teaching complex organizations can be maximized when our integrative framework is used in combination with other existing methods and tools to enhance the necessary cognitive skills. For example, one way in which to enhance our integrative framework's effectiveness is to use it through team-based learning. In this way, students can collaboratively create activity-system maps and run computer simulations, which stimulate all analytical, systems, and design thinking among students. Furthermore, other tools designed to teach necessary cognitive skills can be used simultaneously with our integrative framework (e.g., the causal loop diagram used to teach design thinking; Atwater et al., 2008). Students can apply what they have learned in other classes when conducting integrative case studies to understand complex organizations under dynamic environments. In short, our integrative framework can complement other tools to teach such cognitive skills as systems and design thinking.

As our case demonstration showed, the integrative framework can generate more opportunities to apply the rich accumulation of the research findings from the NK model studies, which might be too abstract to explain to business students when it is used alone. This approach narrows the gap between academic research and business education. Furthermore, with visible experiment- and evidence-based outcomes, this approach can facilitate a discussion about how to create competitive advantages for organizations. By visually learning organizational performance and resilience in various environments, business students will have an opportunity to think about how to balance different actions (e.g., a local search versus long jumps) in dynamic environments, as well as how quickly a business may return to normal operation levels in the case of business shocks.

Business educators and students need to be aware of the true purpose and the intended educational effect of our demonstration examples. That is, the use of case studies in our integrative framework focuses on exemplifying the interdependent activities of organizations. In the interest of parsimony, the aim is not to predict company performance. The case studies reduce the level of abstraction and help with visually understanding how differences in degrees of interdependence and strategic focus influence organizational performance in dynamically changing environments. In this way, the integrative framework offers traceable experiment-based insights, facilitate students' visible understanding of the change process of complex organizations in different business scenarios, and increase the likelihood of appropriate actions.

Limitations and Future Directions

Our approach of integrating the analysis of activity-system maps in the NK model naturally has a number of limitations, mainly stemming from the technical abstraction of any actual situations. The model's reflection of reality and the inherent limitations are largely dependent on the parameters and assumptions made (Davis et al., 2007; Hughes et al., 2012). For instance, we made a simplifying assumption that an activity-system map serves as an abstraction of any company and remains unchanged over time, even after turbulent environments have manifested. In particular, although we consider such factors as activity-system maps, interaction matrices, and performance landscapes, we have not included other issues. These issues include the incurred cost of an organization's exploration strategy, the operational efficiency of activity connections, or any internal communication processes for making decisions.

Several promising areas are in need of future research. First, we endorse the potential of integrating the existing theoretical principles with computational modeling in business education. For example, the concept of the rugged performance landscape in the NK model can be a good metaphor for business students to understand the nature of the interdependencies of business activities or decisions, as well as their relationships with complex environments. Therefore, future research could further explore the application of the rugged performance landscape as a metaphor in organization management fields. Additionally, the sequential combination of graphical mapping tools and the computer simulation of mathematical models has the potential to generate other effective teaching tools besides the combination of activity-system maps and the NK model. Indeed, many other mapping tools are available in business education (Angwin et al., 2019), and several simulation methods are also performed in management research (Davis et al., 2007), some of which can be combined for effective business education.

Future research could also involve conducting empirical studies to examine the teaching effectiveness of using our framework. For example, future research could conduct a randomized controlled field experiment (e.g., Zhu, Bischoff, Kaap, Schmidt, Gielnik, & Frese, 2020) to investigate the training effectiveness of the integrative approach or its combination with other teaching methods (e.g., design thinking training) by comparing it with typical lectures or the component of the integrative approach only (e.g., activity-system maps or the NK model only).

In conclusion, we believe that this integrative approach can open a new avenue for business education. In addition, it can equip business students with critical cognitive skills and tools designed to enhance their abilities to understand and manage complex organizations in dynamic environments.

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FIGURE 1
A Four-Step Integrative Framework of Activity-System Maps and NK Model to Understand Organizational Performance Under Dynamic Environments

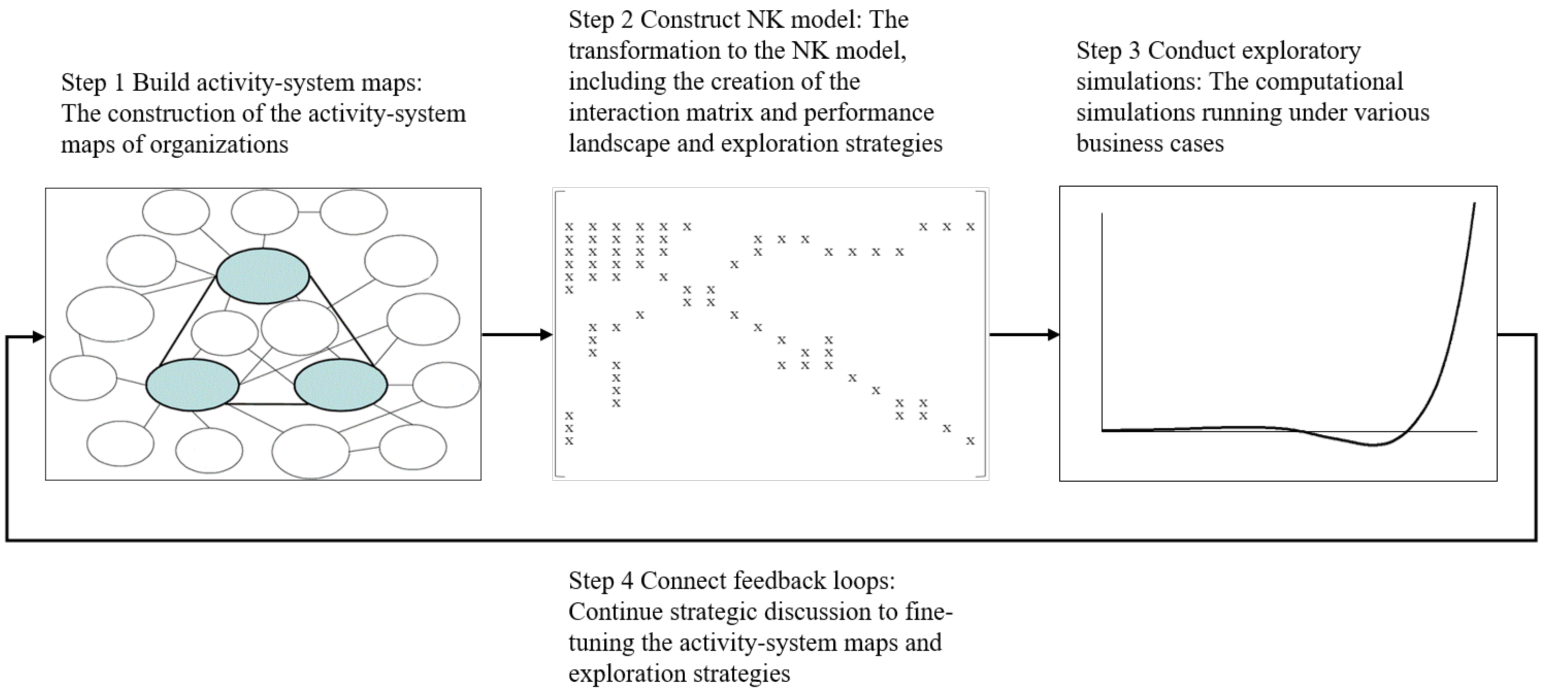
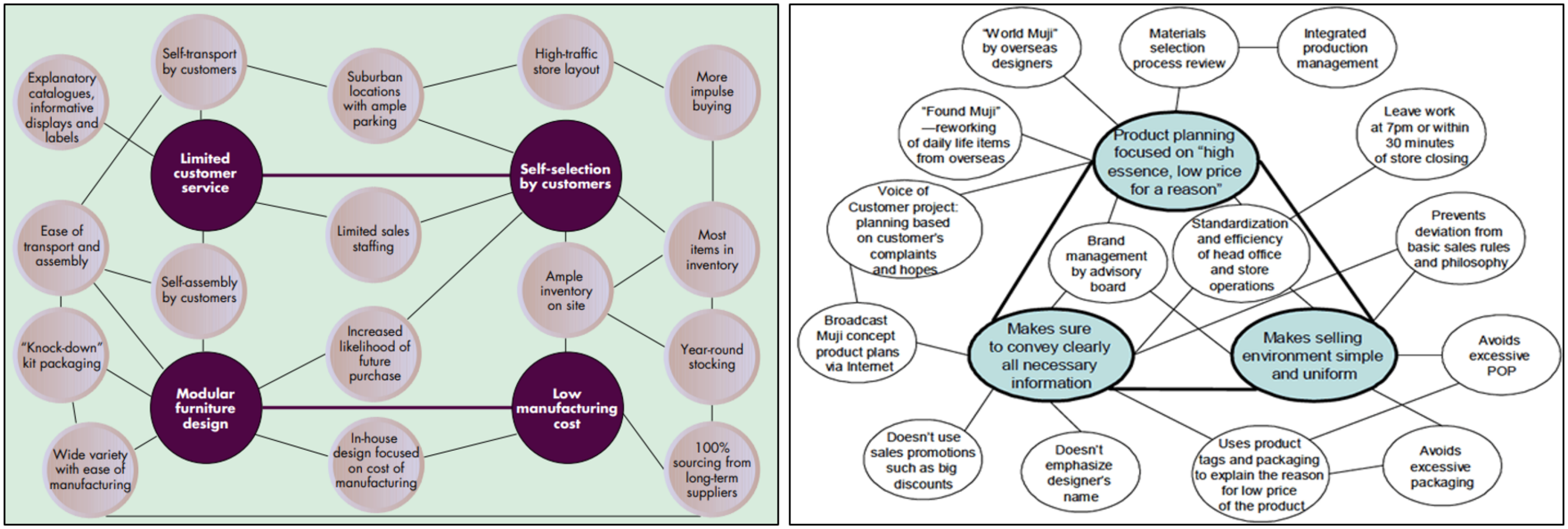


FIGURE 2
Activity-System Maps

(2a) IKEA [1] (2b) MUJI [2]



Notes. (1) Porter (1996); (2) The Porter Prize (2007).

FIGURE 3
Interaction Matrices [1]

(3a) IKEA (N = 20, K = 3.3)

X	X			X			X											X	X
X	X			X	X	X		X			X								
		X	X		X								X	X					
		X	X			X	X							X	X	X	X		
X	X			X															
	X	X			X						X	X							
	X		X			X													
X			X				X										X		
	X							X	X										X
								X	X	X									
									X	X	X								
	X				X					X	X	X							
					X						X	X	X						
		X										X	X		X				
		X	X											X					
			X										X		X	X			
			X												X	X	X		
			X													X	X		X
X																		X	
X																	X		X

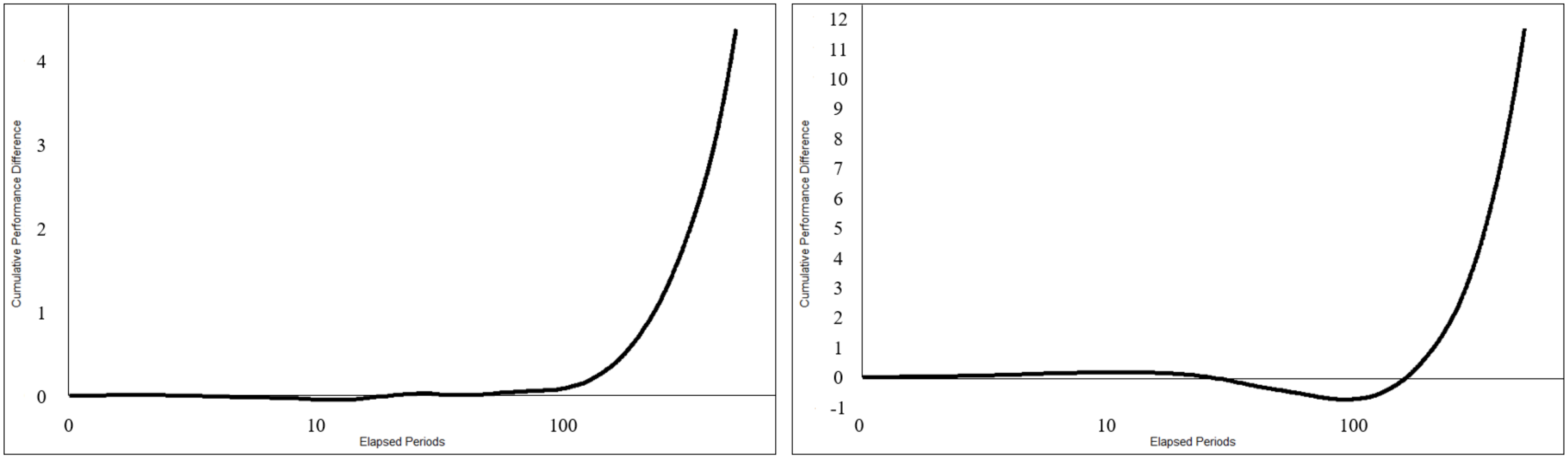
(3b) MUJI (N = 18, K = 2.9)

X	X	X	X	X	X										X	X	X
X	X	X	X	X				X	X	X							
X	X	X	X	X				X			X	X	X	X			
X	X	X	X				X										
X	X	X		X													
X					X	X											
					X	X											
			X				X										
	X	X						X									
	X								X		X						
	X									X	X						
		X							X	X	X						
		X										X					
		X											X				
		X												X	X		
X														X	X		
X																X	
X																	X

Notes. (1) An X in column *j*, row *i*, denotes that activity *j* affects activity *i*; N denotes the number of activities; K denotes the number of interdependencies between each activity and other activities.

FIGURE 4
The Cumulative Performance Differences

(4a) IKEA (1) (3) (4b) MUJI (2) (3)



Notes. (1) Between the medium and low exploration strategy; (2) Between the customer-oriented and low exploration strategy; (3) *x*-axis in logarithmic scale.

FIGURE 5
Comparison of IKEA Performance Between Stable and Turbulent Environments

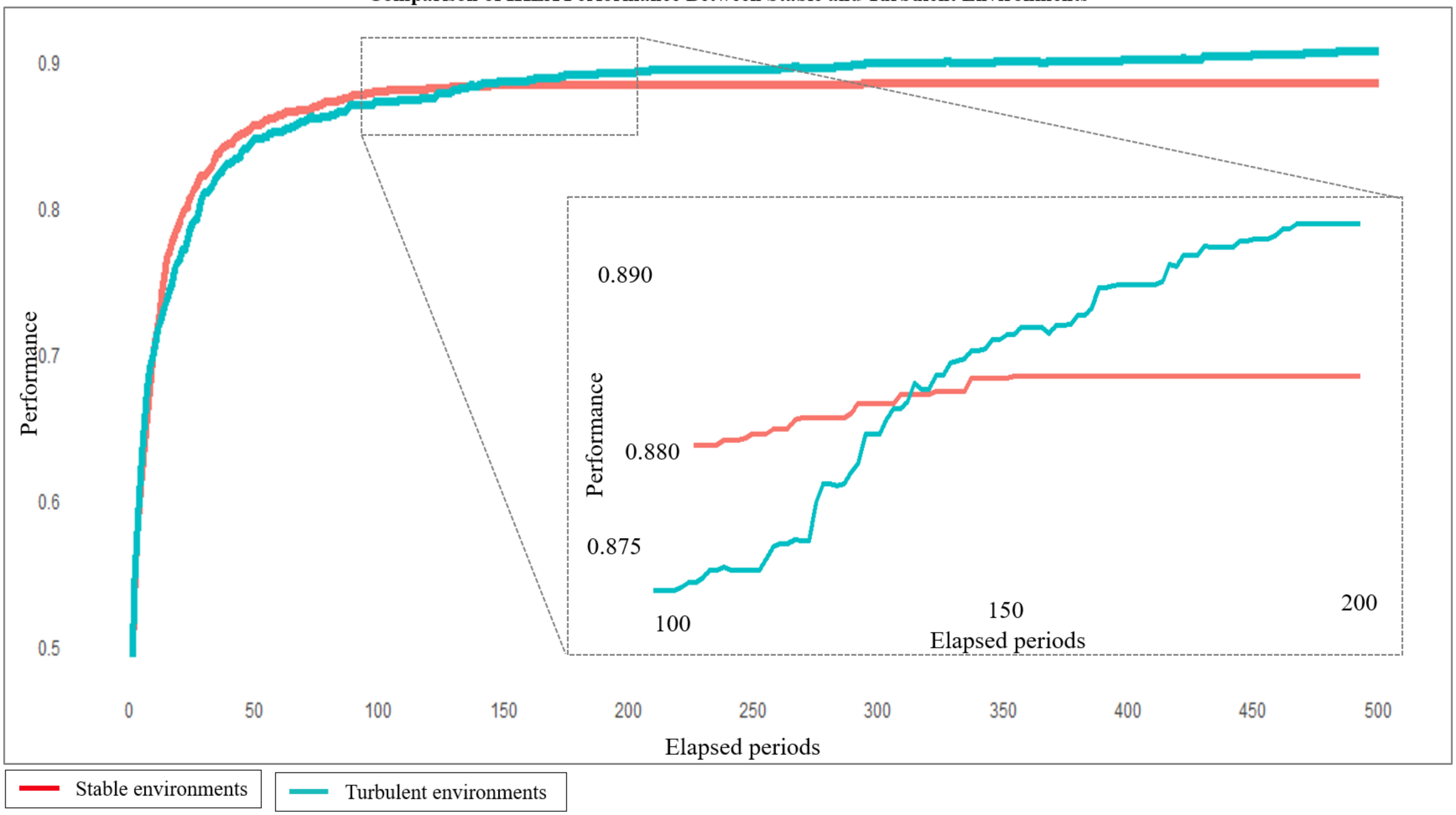


FIGURE 6
Comparison of MUJI Performance Between Stable and Turbulent Environments

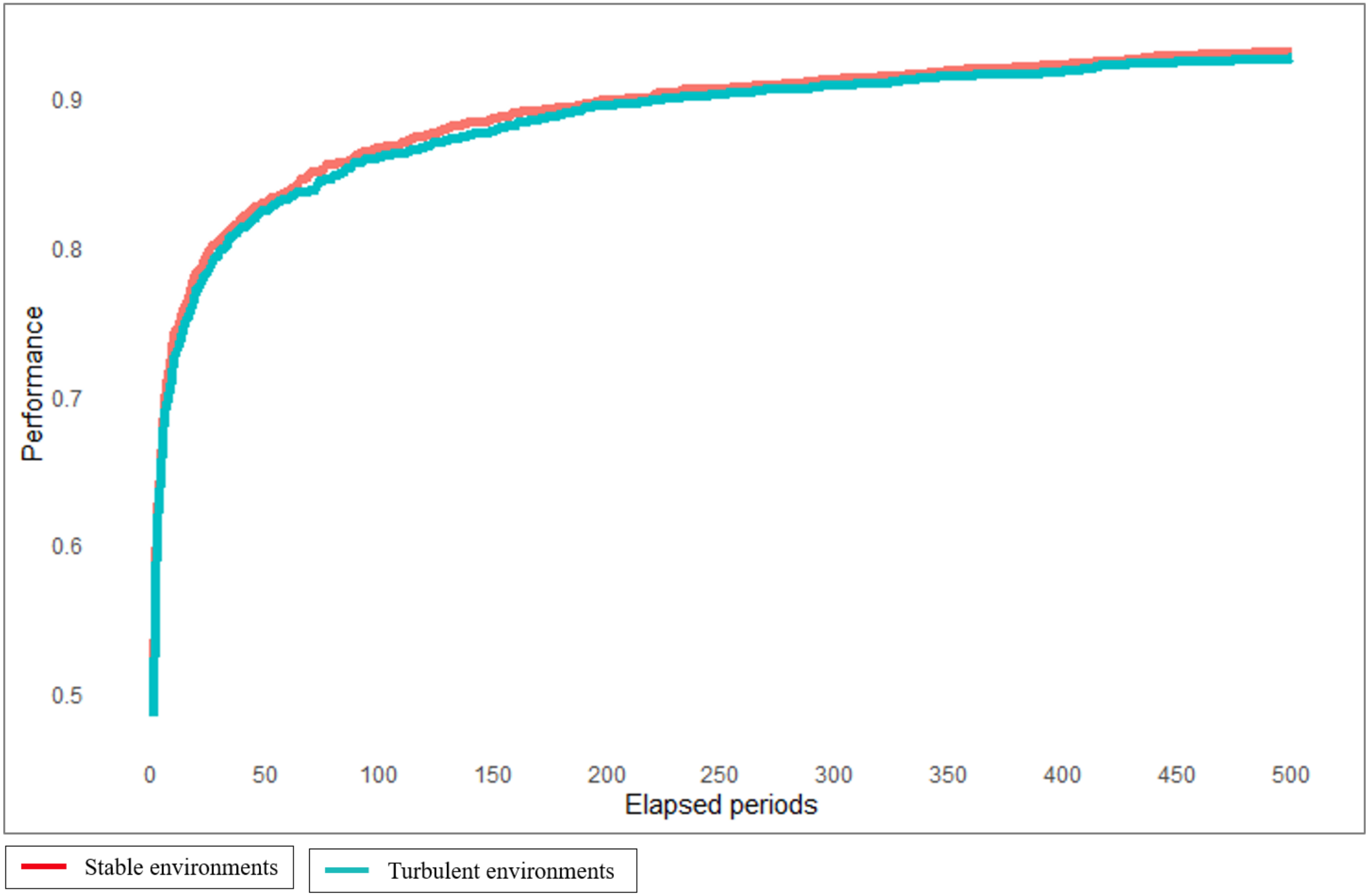


FIGURE 7
Comparison of Four Levels of Organizational Performance Recovery

(7a) IKEA (7b) MUJI

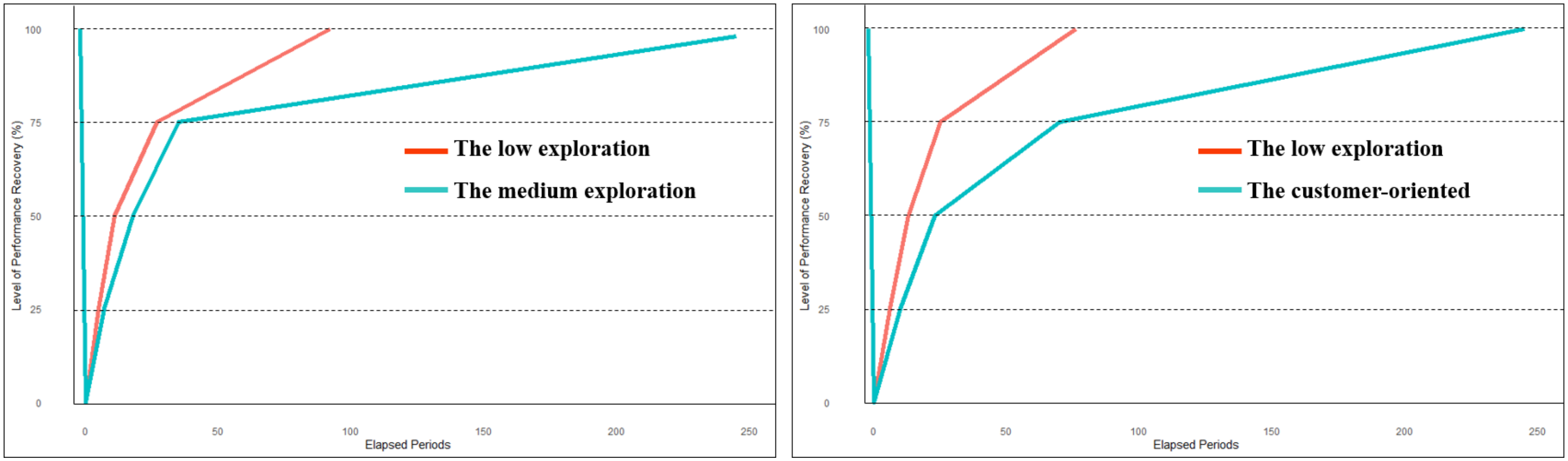
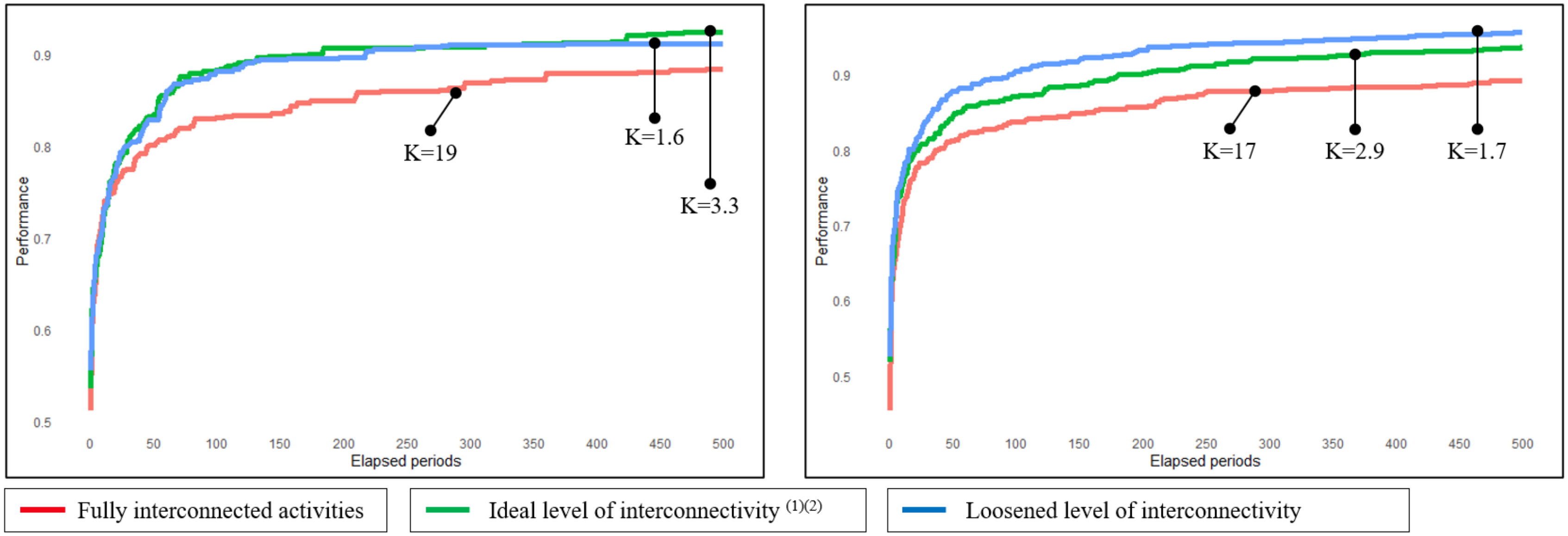


FIGURE 8
Performance Development of Different Levels of Activity Interaction

(8a) IKEA with a moderate exploration strategy (8b) MUJI with a customer-oriented exploration strategy



Notes. (1) Porter (1996): IKEA; (2) The Porter Prize (2007): MUJI.