Nature-inspired organizational design framework for open collaboration platform development

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Abstract

Over the last two decades, for-profit and non-for-profit organizations have increasingly adopted open collaboration, such as open innovation and crowdsourcing, as a strategy for innovation. Information and communication technology (ICT) has played a major role in forming open collaboration communities, but organizational design also needs to be considered to encourage the active participation and collaboration of actors. Nonetheless, organizational design aspect has seldom been addressed in developing open collaboration platforms.
In this research, an organizational design framework for open collaboration was developed through a nature-inspired design approach. This framework suggests that the self-organization mechanism of social insects provides inspirations for the design of the platform, especially in terms of setting simple rules to induce behaviors of the actors and facilitating interactions among them. Since the open collaboration strategy depends on external actors who are not in employment relationship, an organization cannot force their contribution. Accordingly, the organization's capability to induce the spontaneous participation of actors is essential, and it implies the potential role of designers in platform design based on a thorough understanding of actors. We thus claim that designers can bring a new perspective to organizational design. Open collaboration platforms serve as an exemplar in which designers contribute to the design of an organizational environment that fosters collaboration.

Keywords: Bio-inspired design, biomimetics, Crowdsourcing, Open Innovation, Platform strategies

As social and environmental problems become increasingly complicated, social innovators are adopting open innovation strategies (Murray, Caulier-Grice, & Mulgan, 2010). This collaborative approach to innovative problem-solving, such as open innovation and crowdsourcing, is referred to as open collaboration (Levine & Prietula, 2013). In open collaboration, the involvement of stakeholders including citizens in social innovation process is critical to understanding problems and generating ideas in daily life (Aitamurto, Holland, & Hussain, 2015; Bjögvinsson, Ehn, & Hillgren, 2012). Thanks to the development of information and communication technology (ICT), now more stakeholders can participate in the design process in a more convenient way through social media and social network services

(Hagen & Robertson, 2012). Considering expanded design scopes into systems and environments (Bjögvinsson et al., 2012) and open collaboration cases based on ICT (Forte & Lampe, 2013; Seltzer & Mahmoudi, 2012), collaboration platforms could be a proper design object. By designing platforms which are attractive and convenient for the crowd, designers would be able to support the open collaboration of diverse stakeholders and contribute to social innovation.

Although advanced ICT has taken a critical role in facilitating crowd collaboration in diverse fields, it is not a sufficient condition to take advantage of collective intelligence. Organizational design that is suitable for increased amount of information and new relationships between stakeholders should be taken into account (Snow, 2015). How, then, should the organizational design approach be modified for and reflected in the collaboration platform design? In this research, self- organization, which is introduced as one of the principles of open innovation (Murray et al., 2010), was given prominence. In particular, self-organization mechanism of social insects was investigated since bees and ants have been appreciated in the management field for their excellent self-organized performance based on simple rules (Bonabeau & Meyer, 2001; Mead, 2014). The potential of the natural ecosystem as a source of inspiration for innovative solution for organizational problems has been suggested by several studies (Fewell, 2015; Holbrook et al., 2010; Mead, 2014) and empirical cases (Bonabeau & Meyer, 2001). Since both a social insect colony and a community for open collaboration pursue collaboration based on reciprocal relationships among a crowd of members (Gulati, Puranam, & Tushman, 2012), self-organization mechanism of social insects could be a good source of inspiration for designing an open collaboration system. Accordingly, this research aims at suggesting an organizational design framework for open collaboration based on self-organization phenomena in nature. Along with this aim, the following research questions will be addressed:

(1) How do we apply the mechanism of self-organization to organizational design for an open collaboration platform?

(2) How can designers contribute to applying the self-organization mechanism to organizational design for an open collaboration platform?

Open Collaboration

Diverse studies have shown different views on open innovation, crowdsourcing, and open collaboration as delineated in Table 1.

Table 1 Varying perspectives on open innovation, crowdsourcing and open collaboration

	Open innovation	Crowdsourcing	Open collaboration
Schenk and Guittard (2011)	Open innovation focuses on the innovation processes and interactions between firms	Crowdsourcing addresses the broader application scope of the relationship between a firm and the crowd	-
Estellés-Arol*as* & *González-Ladrón-De-Guevara (*2012*)*	Crowdsourcing is a process to facilitate open innovation		-
Seltzer & Mahmoudi (*2012*)	Crowdsourcing is a technique to facilitate open innovation		-
De Vreede et al. (2013)	-	Open collaboration is one of the three types of crowdsourcing. Different from the other two types which encourage competition among the participants, a solution is synthesized through the collaboration of participants in an open collaboration.	
Forte & Lampe (*2013*)	-	Tasks are conducted without interaction between the workers in crowdsourcing	Open collaboration facilitates social interaction and collaboration between participants
Levine and Prietula (2013)	Open collaboration is a generalized concept embracing open innovation, crowdsourcing and other similar phenomena		

Previous studies on open innovation, crowdsourcing and open collaboration imply that making a clear definition of and distinction among them is not a simple work. Nonetheless, in this study, open collaboration was selected as a representative term to emphasize the significance of collaboration in **social innovation**. To integrate the findings from the literature reviews, open collaboration needs to (a) involve a crowd, (b) encourage voluntary participation of a crowd, (c) provide a mutual benefit, (d) facilitate interaction and synergy among crowd members, and (e) allow transparent and participatory decision-making.

The requirements of open collaboration can be implemented in online platforms thanks to advanced ICT (Cabiddu, Castriotta, Di Guardo, & Floreddu, 2013; De Vreede et al., 2013; Forte & Lampe, 2013). However, this does not mean that technologies promise the active collaboration of a crowd. An open collaboration community engages autonomous participants of equal status through an open system, so a conventional organizational structure and management method are unfavorable for attracting these participants (Gulati et al., 2012). Therefore, the organizational design for open collaboration aims at integrating different actors into a networked community and allocating resources, tasks and decision-making power for mutual benefit of all stakeholders (Baldwin, 2012). The significance of organizational design is emphasized especially when technologies are utilized to induce the participation and collaboration of the crowd (Kornberger, 2016).

Organizational design for open collaboration

In accordance with the importance of organizational structures in strategy change (Fjeldstad, Snow, Miles, & Lettl, 2012; Snow, 2015), several suggestions on organizational forms for open collaboration have been made recently. The previous studies introducing the elements of organizational design for open collaboration are summarized in Table 2.

Table 2 The summary of organizational design elements for open collaboration

Source	Elements of Organizational Design for Open Collaboration
Meta-organizational design (Gulati, 2012)	**Permeability of boundaries** - the strictness of the procedure to become a member of a community - a closed boundary is easier to manage an open boundary is better for inviting more participation
	Degree of stratification - the differentiation of roles and the status of members - A hierarchical structure: simple management and higher motivation to take higher status - A heterarchical (equal) structure: higher ownership and attachment to the organization but difficulties of reaching an agreement
Actor-oriented organizational scheme (Fjeldstad et al., 2012)	**Actors** who have the capabilities and values to self-organize
	Commons where the actors accumulate and share resources
	Protocol/processes/infrastructures that enable multi-actor collaboration
The principles or organizational design for business ecosystems (Baldwin, 2012)	**Proprietorship of core components** the owners of a platform, which is an irreplaceable core component in the business ecosystem, have discretion in the business
	The number of for-profit owners of the core components Participants of the platform, who produce optional components, prefer platforms with small numbers of owners so that they can claim a larger portion of the profit
Task and knowledge contingencies (Lakhani et al., 2013)	**Task decomposition** Open innovation strategy is advantageous when the tasks are modularizable
	Problem-solving knowledge distribution Open innovation strategy is advantageous when the knowledge required for problem-solving is broadly distributed
Design principles for organizing distributed innovation (Kornberger, 2016)	**Interface design** - manage the interactions and information exchanges among the actors - 'meeting points' mediating inside and outside the organization and the interface for smooth communication between subsystems
	Architectures of participation - Modularity: the tasks should be modularized so that scattered actors can handle the tasks independently - Granularity: the size of the task modules must be small enough to be completed by the members

	- Integration efficiency: the completed modules of the tasks should be easily and efficiently integrated
	Evaluative infrastructure - visualize implicit values of the work process and results - underpin the decision-making process - be perceived as a new value in the community

Although the aforementioned five studies have different frameworks to articulate the organizational scheme for open collaboration, they embrace a common point: a desirable organizational design for open collaboration necessitates certain environmental conditions for collaborative and communication activities. These activities facilitate the actors' voluntary participation.

To maximize the performance of the autonomous independent units, they need to be supported by the platform (Gray & Vander Wal, 2014). On a platform, technology facilitates the interaction between the actors and resources so that they can generate and exchange value (Parker, Van Alstyne, & Choudary, 2016). The problem is that developers and designers are not used to designing a platform that can support the diverse interactions in a large user community (Gray & Vander Wal, 2014).

Designing the local level rules to induce global-level behavior is extremely tricky because of the difficulties in anticipating the global pattern from the local conditions (Elmenreich & Friedrich, 2009). Self-organization in nature has the characteristics that are in many ways common with the organizational forms for open collaboration (Gulati et al., 2012). We may then be able to learn from it to design protocols and platforms for open collaboration.

Mechanism of self-organization

Self-organization refers to "a process in which pattern at the global level of a system emerges solely from numerous interactions among the lower-level components of the system (Camazine, 2003:8)." Self-organization can be observed from diverse types of living and non-living entities, such as a school of fish or a pattern in tidal sand. Nonetheless, the collaboration of social insects such as nest construction by bees and foraging by ants (Detrain, Deneubourg, & Pasteels, 1999) are the most representative examples that show the power of self-organization.

The self-organization of social insects emerges from feedback loops based on iterative local interactions (Fewell, 2015). An entity acquires information through direct communication with other individuals or through so-called stigmergy, indirect communication using a shared environment as the media. This information is transmitted in the form of either signals or cues: signals are the conspicuous stimuli that have developed in the evolution process, the cues are incidental and subtle (Camazine, 2003). Based on the signals and cues, individuals make decisions how to behave. In the process, their decision-making is affected by biological and

physical parameters: biological parameters are innate characteristics of the organisms, and physical parameters are related to environmental or physical conditions.

Finally, the accumulation of individual interactions leads to positive and negative feedbacks for the colony. Specifically, when the colony members find an attracting signal made by co-workers, more of them participate in the activity, and the signal becomes even stronger. After the task is done, they stop generating the signal, and the collaborative group dissolves naturally (Allen, 2010). In this decentralized manner, the community resolves intricate problems at a systematic level.

To conclude, self-organization enables a community to achieve complex and large-scale outcomes through the collaboration of a large group of members. The individual members communicate locally, make decisions, and enact them according to a set of simple rules programmed in them and the environmental changes. Figure 1 summarizes the mechanism of self-organization. In this mechanism, a single actor does not need to understand the global conditions nor need direct control; it is similar to the organizational design approach for open collaboration. Self-organization strategy reduces the burden of information acquisition, information processing, and decision-making on individuals (Camazine, 2003). Furthermore, the failure of one or several individuals is not critical for the success of the community, and communities can easily adapt to environmental changes (Bonabeau & Meyer, 2001). For these advantages in terms of robustness and flexibility, the self- organization strategy is effective in handling dynamic problems (Holbrook et al., 2010). Considering the strengths of self-organization and the analogy between self-organization and the organizational design approach for open collaboration, self-organization can be an inspiration for the design of open collaboration platforms.

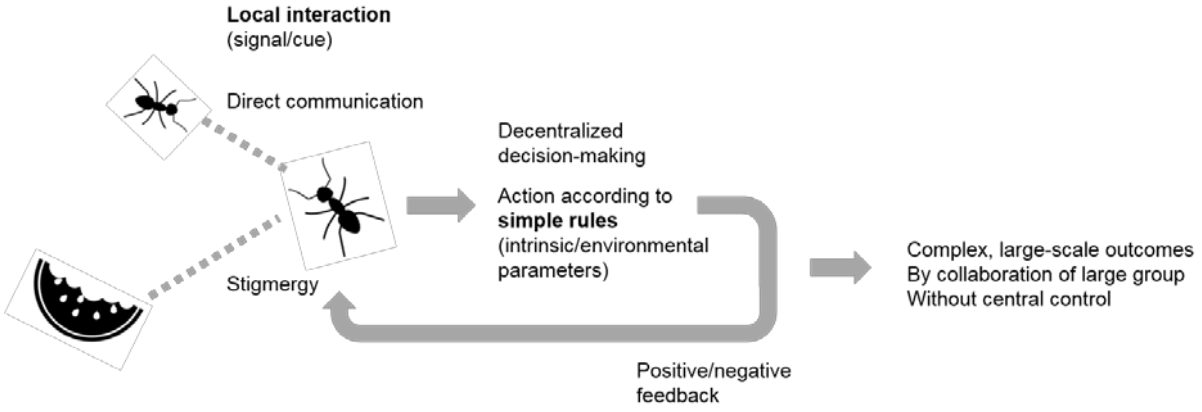

Figure 1 Summary of the self-organization mechanism

An organizational design framework for open collaboration

Based on the literature studies on organizational design for open collaboration and the self-organization mechanism, an organizational design frame was established. This framework consists of 5 elements: (a) organizational goals / required tasks & resources, (b) actors, (c) commons, (d) task design, and (e) information communication. The issues addressed in the previous studies are associated with these elements of the framework (Table 3). This framework was then applied to designing the structure of an open collaboration platform (Figure 2).

Table 3 Organizational design issues within the framework

	Meta-organizational design (Gulati, 2012)	**Actor-oriented organizational scheme (Fjeldstad et al., 2012)**	**The principles or organizational design for business ecosystems (Baldwin, 2012)**	**Task and knowledge contingencies (Lakhani et al., 2013)**	**Design principles for organizing distributed innovation (Kornberger, 2016)**
(a) Organizational goal / Required tasks & resources				Task decomposition Problem-solving knowledge distribution	
(b) Actors	Permeability of boundaries Degree of stratification	Actors	The number of for-profit owners of the core components		
(c) Commons		Commons	Proprietorship of core components		
(d) Task design		Protocol/processes/ infrastructures			Architectures of participation
(e) Information communication					Interface design Evaluative infrastructure

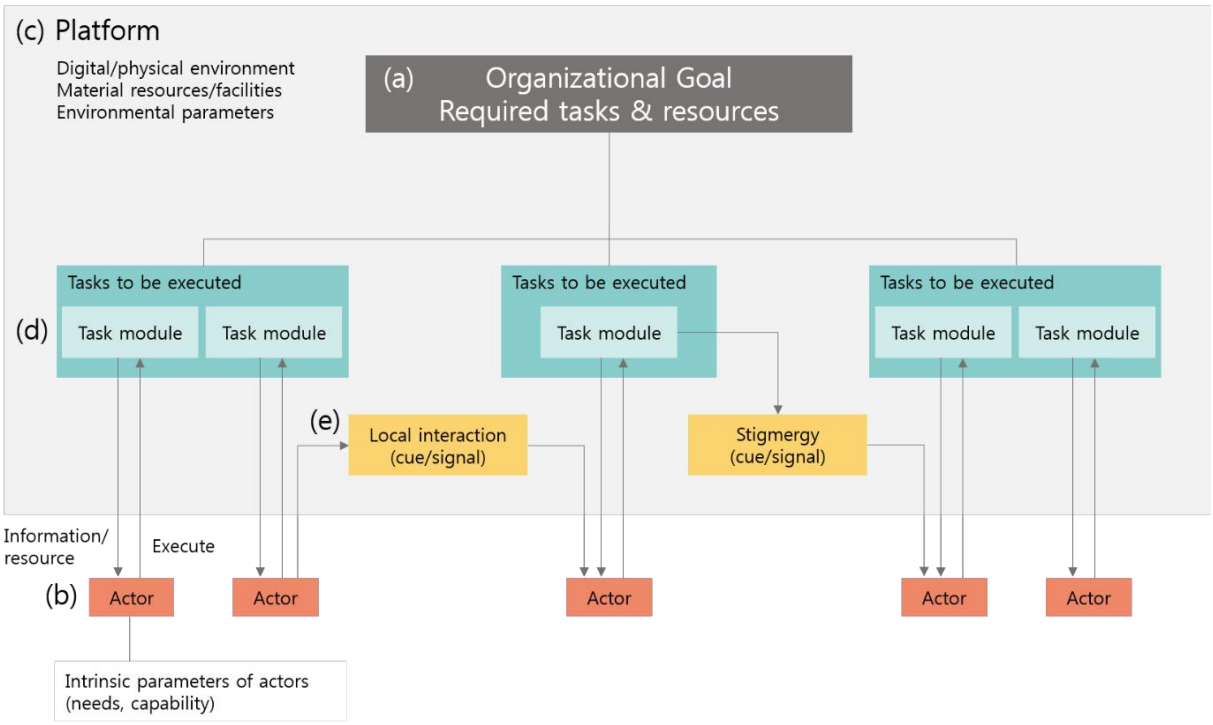

Figure 2 The outline of the operation of an open collaboration platform

(a) Organizational goal / required tasks & resources

An organization is composed to achieve the organizational goals, and it is equivalent to the global- level pattern that emerges from the self-organization approach. According to the goal, the tasks to be executed are clarified. Each task entails requirements to be completed, such as capabilities or resources, and these resources include information and human resources as well as material resources and facilities. After clarifying the organizational goal, tasks and requirements, the suitability of open collaboration strategy is evaluated depending on the decomposability of tasks and the degree of knowledge distribution. Open collaboration is effective when the tasks can be divided and assigned to multiple workers and the necessary knowledge can be acquired only through the collaboration of several actors.

(b) Actors

Basically, actors are invited through an open call (Estellés-Arolas & González-Ladrón-De-Guevara, 2012). However, the high permeability of a community boundary includes the risk of involving disqualified members and contributions. To avoid such a risk, an organization can provide attractive elements for target users and execute prescreening or post management on members' contributions.

Analogous to the biological parameters of social insects, the intrinsic characteristics — mental model, needs and capabilities — of actors are also the important factors in organizational design. Even though the community members are provided with same stimuli, the behaviors of individuals may vary depending on their intrinsic parameters. Thus, the types of actors and their intrinsic parameters are taken into consideration when designing the protocols that influence the active participation and collaboration of actors. In the same context, stratification of an organization is determined depending on whether the desire for a higher position or ownership is influential in motivating a community.

(c) Commons

Commons indicate resources shared by the platform users, including the platform itself (Fjeldstad et al., 2012). Sharing common resources and the environment freely is more effective in encouraging the participation of actors than having exclusive ownership. Regarding self- organization phenomena, commons also include the influential factors on decision-making and the behavior of actors. Through the commons — namely, stigmergy — actors can engage in indirect communication. Thus, the environmental parameters of commons are highly relevant to the information communication aspect of platform design.

(d) Task design

The tasks identified along with the organizational goals are modularized with consideration of the motivations and capabilities of actors so that they can take charge of each module independently. The modules are designed to be integrated easily after all the modular tasks are finished. In particular, positive and negative feedback systems control the collaboration of actors and integrate their work as a collective outcome. In this context, considering how to utilize the information on progress or outcomes of each task as cues or stigmergy can improve the efficiency of the information system for open collaboration.

(e) Information communication

In a self-organized community, entities produce information intentionally (signals) or incidentally (cues), and this information is exchanged through direct (peer-to-peer) or indirect (stigmergy) communication. Especially cues and stigmergies are useful for facilitating expeditious communication. A reservation system is a good example: when a customer choose a seat, the information on seat occupancy is automatically updated and shared with other customers through the seat map, without intentional or direct communication. Thus, the suitable methods of information generation and transmission need to be adopted depending on the context and availability of the information sources.

With respect to evaluation, the scoring of collaborativeness and the quality of outcomes can enhance the motivation and collaboration of actors. Furthermore, collective decision-making

based on the evaluation of individuals is an effective strategy to derive optimized solutions. Since the new values formed in the evaluation process are strongly related to the motivation of actors, the evaluation system designed in line with the intrinsic parameters of actors can encourage participation and collaboration without monetary rewards.

Analysis of an existing platform using the framework

For a better understanding of the applicability of this framework to the platform design, Adopt-A- Hydrant, a platform to support the crowdsourcing of hydrant maintenance in Boston, was analysed using the framework.

(a) Organizational goal / required tasks & resources

The purpose of this platform is keeping the hydrants available and accessible for emergencies. After snow falls, more than 13,000 hydrants in Boston need to be shovelled and cleared of snow. This task can be executed in a more efficient way when it is shared by citizens. The residents who live near a hydrant and possess the equipment and labour capabilities to remove the snow would be suitable for this task. In addition, the information on the location and the condition of the hydrant to be managed is required.

(b) Actors

This service is provided by the city of Boston, but participation on this platform is entirely dependent on the individual citizen. Besides, Adopt-A-Hydrant does not entail a hierarchal structure in its user community.

(c) Commons

In this case, the hydrants in Boston are the objects to be managed and are the media through which citizens can interact indirectly with each other. While the hydrants are physical resources, the Adopt-A-Hydrant online platform and the map with the marking of the hydrants are the digital environment to obtain the required information to adopt a hydrant.

(d) Task design

The task of maintaining the hydrants in Boston was modularized by cleaning one hydrant around the home or the workplace. This modularized task is simple and manageable enough to be handled by individual citizens. Since a modular task includes the entire process of hydrant maintenance, the performance of the tasks hardly affects each other. Thus, the integration of tasks leads to more hydrants being cared for rather than the higher degree of completion of tasks.

(e) Information communication

The most significant information for carrying out the task is the location and adoption status of the hydrants. The platform provides this information on the map: the hydrants already adopted and those that have not yet been adopted are marked with green and red location symbols, respectively. The participants can look through the map or input the address to look for an adoptable hydrant.When an actor finds an appropriate one, he or she can give the hydrant a nickname and register it for adoption by clicking on a red location symbol, whereas clicking the green location marks shows the name of hydrant and the adopter. If a citizen finds a hydrant covered with snow, he or she can send a reminder to the adopter through this hydrant information page. The registration of adopting hydrants is a signal issued by the citizens, but the current state of hydrant adoption in Boston is visualized on the map as the cue.

Discussion

Application of the self-organization mechanism to organizational design

Considering the complexity and broad scope of problems handled in open collaboration platforms, self-organization, which has advantages in distributing the burden of information processing and decision-making, could be a useful strategy. This research reveals the similarities between the self- organization mechanism and the functioning of platforms for open collaboration: achieving organizational goals through indirect control based on autonomous decision-making and activities. Moreover, self-organization mechanism provides some useful concepts which have not been addressed in the previous studies on organizational design for open collaboration. For instance, we can enhance collaboration through applying actors' intrinsic attributes to setting the platform policies, adopting the suitable communication mode between direct interactions and stigmergies or between signals and cues, and facilitating positive or negative feedbacks. Accordingly, we suggested an organizational design framework for open collaboration based on self-organization phenomena.

In addition, the analysis of Adopt-A-Hydrant platform using this framework implies how it could contribute to open collaboration platform design practice. To be specific, the names of a hydrant and its adopter displayed by clicking the green location marks are the elements that make the adopters feel responsibility and attachment to their hydrants. However, this platform lacks the functions for positive feedback. To maximize the effect of stigmergy, the platform could provide processed data such as total number of adopted and unadopted hydrants or local adoption rate, and set communal goals to stimulate the community members. Moreover, functions for inviting neighbors through inter-actor communication could encourage the participation of new adopters. As this analysis shows, elements of this self-organization framework could be utilized as a standard for diagnosing the existing platforms, and further, a guideline to design a new platform. Although the potential of this framework need to be validated through empirical studies, self-organization would be worth considering as a strategy to raise the social impact of an open collaboration platform.

Role of designers in organizational design

While the power of design thinking and design methods has been valued in the management field, the contribution of designers in organizational design has been scarce. In the organizations in industrial economies, the decision-making authority over the organizational form and management strategy has been monopolized by the management, and employees were directly controlled by their supervisors. Thus, designers could rarely intervene in organizational management issues. However, in the organizations using the open collaboration strategy, tasks are performed by external actors who do not work exclusively for the organization. Reflecting this change in the relationship between organizations and workers, recent studies on organizational design are focusing on creating an environment for open collaboration, such as an interface for communication and protocols or a process for task distribution and integration. In this context, platforms can be addressed as an organizational environment, and it implies that the opportunities for designers to contribute to organizational design are expanding.

First, designers can bring new perspectives to organizational design. Attitudes towards devising an optimized solution to a problem and designer methodologies to find a creative solution are beneficial for organizational design for open collaboration. For example, the self-organization mechanism of social insects was used as inspiration for organizational design in this research. Getting inspired by nature is one design approach with a long history, and many nature-inspired design methodologies have been introduced in the design research field. However, most previous studies suggesting the potential of biomimicry for management are based on theoretical investigation rather than empirical verification (Mead, 2014). To promote nature-inspired organizational design as a pragmatic approach for constructing or improving organizations, further studies to provide an organizational design methodology for practical applications and to validate its effectiveness would be necessary. To this end, designers are expected to contribute to deriving design directions from natural principles and executing the solutions (Kennedy, Fecheyr-Lippens, Hsiung, Niewiarowski, & Kolodziej, 2015).

The other task for designers concerns the application of a self-organization mechanism. In the process of developing a framework based on self-organization phenomena, the significance of intrinsic parameters was recognized. With regard to intrinsic parameters, the effect of motivational factors on human behavior is different from that of the behavior of non-human organisms. In addition, human beings have a higher level of autonomy in reaction to external stimulation than social insects, which means that a protocol that is designed based on insufficient apprehension of the intrinsic characteristics of actors has the risk of resulting in totally different behavior patterns from the expectations. Accordingly, a fundamental understanding of motivational factors and their influences on behavior, especially collaborative behaviors, are needed. The differences of needs and motivations between different groups of actors should be clearly identified and applied to the platform design process. Considering the traditional role of designers, i.e., extracting implicit user needs and providing users with satisfying products, we believe that designers are apt to design an external environment that

attracts the spontaneous participation of actors. Nevertheless, additional expertise, such as system design and organizational design, is required for designers to take part in platform design.

Conclusions

In this research, an organizational design framework for designing an open collaboration platform was developed based on the self-organization mechanism of creatures in nature. In particular, the communication patterns that can be observed in nature, such as the feedback effect through local interaction and stigmergy, show how the information system can be improved to enable efficient communication and collaboration between the actors. Additionally, the application of self- organization phenomena to organizational design stresses the importance of consideration on the intrinsic characteristics of participants in organizational design, which means that designers have more opportunities in organizational design than before.

The practical contribution of this research is the introduction of a conceptual foundation for open collaboration platform development. The framework inspired by self-organization encompasses the design issues that were suggested in the previous studies on organizational design for open collaboration. The analysis of the existing platform using the framework also implies that this framework could be a guideline for the integrated platform design approach and contribute to improving platforms. Improvement of the open collaboration platform would encourage the participation of diverse actors in the process from problem identification to solution implementation and contribute to establishing participatory culture in social innovation in the long run.

Regarding the academic contribution, this research calls for interdisciplinary collaboration to promote innovation. In this research, biological phenomena were investigated to generate inspiration for organizational design, which has mainly been handled in the management field. Additionally, the potential contribution of designers in the application of the self-organization mechanism to organizational design for the open innovation platform was suggested. Accordingly, collaboration among researchers in biology, management and design are necessary for further progress in this research. To devise a new organizational design to support the novel innovation strategy based on advanced ICT, the approach to design an organization also needs to evolve. In this context, this research implies that unfamiliar knowledge and perspectives of different disciplines could generate inspiration for innovative solutions.

Nonetheless, the limitation of this research is that the framework was developed using a theoretical approach. To complement these limitations, the effectiveness of nature-inspired organizational design needs to be examined by empirical validation. For future work, the tools and processes to design the open collaboration platforms will be developed based on this

framework, and tested through practical applications.

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