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Pro-socially motivated interaction for knowledge integration in crowd-based open innovation

Yao Sun, Philipp Tuertscher, Ann Majchrzak and Arvind Malhotra

Abstract

Purpose – *The purpose of this paper is to study how the online temporary crowd shares knowledge in a way that fosters the integration of their diverse knowledge. Having the crowd integrate its knowledge to offer solution-ideas to ill-structured problems posed by organizations is one of the desired outcomes of crowd-based open innovation because, by integrating others' knowledge, the ideas are more likely to consider the many divergent issues related to solving the ill-structured problem. Unfortunately, the diversity of knowledge content offered by heterogeneous specialists in the online temporary crowd makes integration difficult, and the lean social context of the crowd makes extensive dialogue to resolve integration issues impractical. The authors address this issue by exploring theoretically how the manner in which interaction is organically conducted during open innovation challenges enables the generation of integrative ideas. The authors hypothesize that, as online crowds organically share knowledge based upon successful pro-socially motivated interaction, they become more productive in generating integrative ideas.*

Design/methodology/approach – *Using a multilevel mixed-effects model, this paper analyzed 2,244 posts embedded in 747 threads with 214 integrative ideas taken from 10 open innovation challenges.*

Findings – *Integrative ideas were more likely to occur after pro-socially motivated interactions.*

Research limitations/implications – *Ideas that integrate knowledge about the variety of issues that relate to solving an ill-structured problem are desired outcomes of crowd-based open innovation challenges. Given that members of the crowd in open innovation challenges rarely engage in dialogue, a new theory is needed to explain why integrative ideas emerge at all. The authors' adaptation of pro-social motivation interaction theory helps to provide such a theoretical explanation. Practitioners of crowd-based open innovation should endeavor to implement systems that encourage the crowd members to maintain a high level of activeness in pro-socially motivated interaction to ensure that their knowledge is integrated as solutions are generated.*

Originality/value – *The present study extends the crowd-based open innovation literature by identifying new forms of social interaction that foster more integrated ideas from the crowd, suggesting the mitigating role of pro-socially motivated interaction in the negative relationship between knowledge diversity and knowledge integration. This study fills in the research gap in knowledge management research describing a need for conceptual frameworks explaining how to manage the increasing complexity of knowledge in the context of crowd-based collaboration for innovation.*

Keywords *Knowledge integration, Open innovation, Knowledge diversity, Crowd, Idea generation, Pro-socially motivated interaction*

Paper type *Research paper*

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Introduction

Open innovation is an expected business strategy for firms today (Afuah and Tucci, 2012; Chesbrough, 2003), used for everything from the creation of user-adapted products (von Hippel, 2005) to open strategy formulation (Whittington, 2015), from solving heuristic-based problems (Boudreau *et al.*, 2011) to solving ill-structured problems (Cairo *et al.*, 2015;

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Majchrzak and Malhotra, 2020); Malhotra and Majchrzak, 2019; Natalicchio *et al.*, 2017). Advanced communication and collaboration technologies are used to make this possible. Open innovation challenges ask crowds to offer innovative ideas, defined as novel and usable ideas, following Piezunka and Dahlander (2015) and Amabile (1988). Idea generation by the crowd provides the sponsoring organization with the potential of obtaining innovative product, service and business model ideas from outside the organization's boundaries (Afuah and Tucci, 2012).

Successful knowledge management provides the foundation for innovation. Knowledge management for innovation plays a critical role not only in international business and inter-organizational activities (De Long and Fahey, 2000; Kuemmerle, 2002) but also in intra-organizational teamwork and collaborations (Hu and Liden, 2015). Knowledge management often occurs "within an intricately structured social context" (Thomas *et al.*, 2001, p. 863), in which social knowledge is tacit and needs to be decoded through effective interaction and narrative (Linde, 2001). As such, motivated knowledge contributors often tend to favor knowledge management systems that facilitate interaction and enable coordination, so that their diverse ideas can be better shared and communicated (Malhotra and Galleta, 2003). Driven by emerging technologies, knowledge management is evolving toward new approaches that rely on open collaboration, collective intelligence and improved communication for knowledge sharing (von Krogh, 2012). Crowd members' collective engagement is shifting the focus of knowledge management to a collaborative and conversational knowledge creation process (Wagner, 2006). Our present study, therefore, seeks to provide a conceptual framework for these emerging approaches to knowledge management, as well as to advance the scholarly understanding of the increasing complexity of knowledge management in the context of crowd-based collaboration for innovation.

Historically, a common practice in off-line contexts for creating innovative ideas is through the integration of diverse knowledge by different specialists (Grant, 1996). However, in online contexts such as crowd-based open innovation, the research on the effect of diversity presents a conundrum (Bingham and Spradlin, 2011; Dahan and Mendelson, 2001). While individuals in small groups can rely on shared cognitive mechanisms to build a common understanding among diverse knowledge domains (Hollingshead, 1998; Wegner, 1987), knowledge integration appears to be difficult for temporary online crowds because members usually share few offline social relationships and have few opportunities to become familiar with others' diverse knowledge domains (Schenk and Guittard, 2011).

Informed by theoretical frameworks of representational diversity of knowledge (Cronin and Weingart, 2007) and cognitive perspective-taking (Grant and Berry, 2011; Parker and Axtell, 2001), we theoretically explore this conundrum between the difficulty to integrate diverse knowledge, yet the need to integrate diverse knowledge. Knowledge diversity in the present study is defined as the variety of knowledge content shared (Majchrzak *et al.*, 2004; Piezunka and Dahlander, 2015). We ask the following research question: *How are members of the crowd able to generate integrative ideas in open innovation challenge despite the knowledge diversity that imperils such integration?* We hypothesize from this theoretical exploration that online crowds that organically share their knowledge through pro-socially motivated interaction will be able to generate ideas that are more integrative of the diverse knowledge presented by the crowd. We used a multi-level, mixed-effects model to analyze the posts contributed to 747 textual discussion threads distributed across 10 open innovation challenges and found that, as hypothesized, knowledge diversity among the posts in a thread has a detrimental effect on whether the thread generates an integrative idea. However, in those crowds that organically use *pro-socially motivated interaction*, we found that this negative effect is reversed. These findings offer implications both for the potential agency of individuals during open innovation challenges as well as the potential

agency of the platform in guiding the organic emergence of pro-socially motivated interaction.

Conceptual development

This section reviews the literature to describe the importance of knowledge integration in crowd-based open innovation and introduces the possible role the pro-socially motivated interaction may play in mitigating the negative effect of knowledge diversity on knowledge integration.

Knowledge integration in open innovation

Knowledge integration is defined as explicitly combining and incorporating prior knowledge (Buchanan, 1992; Harvey, 2014; Malhotra and Majchrzak, 2014; Pacanowsky, 1995); in the context of an open innovation challenge, the prior knowledge is contributions posted by crowd members in the innovation challenge. On average, a member posts less than twice before leaving the challenge (Majchrzak and Malhotra, 2020). These contributions can be ideas for solutions to the problem posed by the open innovation challenge sponsor, as well as knowledge the contributor has about the problem (such as its persistence, root causes and manifestations). The knowledge is integrated for the purpose of offering a new solution-idea to the problem.

Knowledge integration has been referred to as "the synthesis of individuals' specialized knowledge into situation-specific systemic knowledge" (Alavi and Tiwana, 2002, p. 1030), and it is an important mechanism leading to positive collaborative outcomes (Pan *et al.*, 2007). When team members attempt to collaboratively integrate their knowledge, they are more capable of understanding the differences across knowledge domains and traversing knowledge boundaries to collectively create solutions to problems (Boland and Tenkasi, 1995; Cook and Brown, 1999; Dougherty, 1992; Hargadon and Bechky, 2006; Nonaka, 1994; Tsoukas, 2009). With the collage of varied knowledge shared, collaborators can eventually transform and integrate knowledge into novel solutions (Majchrzak *et al.*, 2012). Similarly, other researchers have also pointed out the importance of knowledge integration when it comes to large-scale collaborative innovation or complex problem-solving (Boh *et al.*, 2007; Grant, 1996; Majchrzak *et al.*, 2004; Tiwana, 2008; Tiwana and Mclean, 2005). Therefore, in open innovation challenges, solution-ideas which integrate others' diverse knowledge are likely to be more systemic, comprehensive of the issues that cause the problem to surface, and sensitive to the issues that may impact the feasibility of the proposed solution.

Despite the importance of knowledge integration in open innovation, virtually all research on crowd-based open innovation focuses on the quality of an idea, not the integration it represents (Zhu *et al.*, 2019 for a review). While many studies examine votes as indicative of the acceptance by the crowd (Piezunka and Dahlander, 2015), acceptance may not be the same as the integration of the others' perspectives. Innovation challenges can encourage knowledge integration not by encouraging votes but by encouraging interactive commenting in which crowd members comprehensively incorporate others' thoughts into their own and collectively make their ideas better (Boudreau *et al.*, 2011; Terwiesch and Xu, 2008; Zheng *et al.*, 2011). However, integrating others' knowledge is difficult, especially if the knowledge being integrated is diverse.

Pro-socially motivated interaction mitigates the negative effect of knowledge diversity on knowledge integration

Referred to as the variety of knowledge content shared during an online discussion thread (Majchrzak *et al.*, 2004; Piezunka and Dahlander, 2015), knowledge diversity in

crowd-based open innovation has been shown to influence the knowledge contributions of others (Majchrzak and Malhotra, 2020; Malhotra and Majchrzak, 2019). In open knowledge production communities, knowledge diversity grows in an evolutionary fashion (Kane and Ransbotham, 2016); as content accumulates, knowledge diversity changes. As such, knowledge diversity is likely to be unique to the time in which a crowd member views the posts in a thread (Mattarelli *et al.*, 2018). Thus, unlike functional or demographic diversity, knowledge diversity is temporally specific. Below we discuss the mechanisms underlying knowledge diversity's negative effect, and pro-socially motivated interaction's positive and mitigating effects.

How knowledge diversity may harm knowledge integration. Integrating knowledge remains a challenge in online settings. One major difficulty that members of the online crowd have in communicating with each other lies in representational gaps (Cronin and Weingart, 2007). A representational gap refers to the differences occurring between collaborators' perceptions of the problem. In open innovation challenges, for example, crowd members' different knowledge and values create diverse problem representations, and these diverse representations may derail collective information processing because members may not be fluent in each other's knowledge domains. For knowledge diversity to have any value to other collaborators, it must be understood by those collaborators, which requires a state of collective mind used in virtual contexts referred to as "common ground" (Cramton, 2001). However, common ground is difficult to develop in open innovation challenges because crowd members lack a common organizational or situational context, show minimal commitment to pursuing a common goal and enter or leave conversations at any point (Faraj *et al.*, 2011; Viscusi and Tucci, 2018). Any common ground about language, any overlaps in knowledge and any agreed-upon formulation of the problem among two members of the crowd is likely to be discarded when a third member joins the interaction (Kane *et al.*, 2014). The crowd members participating in an online discussion cannot easily reestablish common ground each time a new member joins because that would focus the discussion only on common ground and crowd out interactions for knowledge integration and creative synthesis (Harvey, 2014).

Moreover, online individuals have few opportunities to know each other well, thus lacking a prerequisite for knowledge integration identified in a traditional organizational context (Harvey, 2014; Weber and Khademian, 2008). Knowledge diversity in online contexts has been shown to have negative, null or at least inverted U-shaped effects on innovativeness because the knowledge of others is not effectively absorbed by crowd members who could combine that knowledge into integrated ideas (Caner *et al.*, 2017; Fleming, 2001, 2007; Patel and Van der Have, 2010). As collaborators' collective capability of knowledge sharing and integration often depends on shared understanding and in-depth connected communication among members (De Dreu *et al.*, 2000; Kogut and Zander, 1992; Levinthal and Warglien, 1999), in online open innovation challenges, such a capability of the crowd can be limited because of the crowd's diverse knowledge backgrounds and a dearth of common understanding in an ever-evolving communication context. Online crowd members' fluid membership, dynamic relations and the permeable boundaries associated with online communities (Faraj *et al.*, 2011) also pose a challenge to knowledge integration.

The conundrum, then, is that, although the diversity of knowledge posted is at the heart of the potential for innovative idea generation in crowd-based open innovation, this very diversity makes it also difficult to develop the common ground required for deriving the benefits of knowledge diversity. In the particular context of crowd-based open innovation, knowledge diversity, *per se*, will be too difficult to synthesize, leading to lower occurrence of knowledge integration:

H1. In crowd-based open innovation, the higher the level of knowledge diversity present at the time an individual posts an idea, the less likely that the posted idea will be integrative.

How pro-socially motivated interaction facilitates knowledge integration. Online platforms have afforded pro-socially motivated individuals to construct virtual communities to share knowledge and collectively generate solutions to challenging problems (Ellison, 2007; Wagner *et al.*, 2014). In contrast with self-interested motivations, pro-social motivation "is the desire to expend effort based on a concern for helping or contributing to other people" (Grant and Berry, 2011, p. 77). When pro-socially motivated, individuals tend to maximize others' outcomes, or at least try to balance others' outcomes with their own (Deutsch, 1980). Compared to self-focused individuals, those who can use other-focused thinking approaches are better able to provide each other with effective and constructive help, communicate accurately, identify problems and find solutions, encourage and support each other when completing tasks, as well as present positive attitudes to each other (Tjosvold, 1984). Knowledge formation and sharing cannot be completed unless pro-socially motivated interaction happens among collaborators who make their knowledge explicit to each other (Brown and Duguid, 1998).

One major manifestation of pro-socially motivated interaction is perspective-taking, which refers to a cognitive process that enables individuals to understand others' viewpoints (Bartunek *et al.*, 1983) and empathize with others' feelings (Sawyer, 1975). It is rooted in motivated information processing theory (Kunda, 1990), denoting the fact that individuals' desires can shape the way they attend to information. When individuals engage in active perspective-taking, they are more likely to connect others' experiences with their own, empathize with others, show concern for others and identify others' experiences with their own (Betancourt, 1990; Egan, 1990; Aron *et al.*, 1991). As individuals successfully take others' perspectives, they are more likely to attribute positive motives to others' behaviors, and can better recognize others' knowledge, work and ability (Amabile, 1996; De Dreu *et al.*, 2000). Regarding knowledge sharing, in particular, Grant and Berry (2011) examined the relationship between perspective-taking and the emergence of new ideas, indicating that perspective-taking improves the creation of new ideas. They found that when collaborators pay attention to what others are thinking, "they will be more likely to develop ideas that are ultimately useful to others" (p. 77). Research also suggests that people's cognition influences the effectiveness of knowledge management (Scuotto *et al.*, 2017) and that when individuals trust others and exhibit positive attitudes to understand others, the effectiveness of knowledge sharing can be improved (Scuotto *et al.*, 2020). For diverse collaborators, therefore, perspective-taking is a key to success as it facilitates a comprehensive synergy of the members' diverse knowledge (Hoever *et al.*, 2012).

In this regard, pro-socially motivated interaction can catalyze knowledge co-creation and integration, in response to challenges posed by the evolving organizational, economic and institutional environment (Del Giudice and Maggioni, 2014; Della Peruta *et al.*, 2014). Pro-social interaction also relates to the capacity of knowledge retention and exploitation (Dezi *et al.*, 2018). Active pro-social interactions allow group members to connect the current problem to past knowledge to co-create new solutions. In large-scale collective problem-solving, collaborators tend to find solutions through active analogical reasoning, whereby they try to transfer previous knowledge to the current context to make sense of the situation and the task (Hargadon and Bechky, 2006). Additionally, within online knowledge collaboration communities, sharing and integration are largely enabled by members' successful motivated interaction about the mutual understanding across cognitive boundaries and the ultimate construction of a common and integrative view of the problem (Bechky, 2003; Harvey, 2014). Taken together, our study proposes:

H2. In crowd-based open innovation, the higher the level of pro-socially motivated interaction present at the time an individual posts an idea, the more likely that the posted idea will be integrative.

How the downsides of knowledge diversity may be overcome – effects of pro-socially motivated interaction. Pro-socially motivated interaction often leads to a better surfacing of ways to see commonalities (Harvey, 2014). Pro-socially motivated individuals are better able to take others' perspectives in problem-solving (Grant and Berry, 2011). Pro-social members often strive for forging trusting relationships with others, developing positive perceptions and attitudes, contributing constructive opinions and understanding others' perspectives in group collaborations (Pruitt, 1998). In organizational knowledge management, pro-socially motivated knowledge contributors exhibit a high level of perspective-taking and thus a low level of knowledge hiding (Škerlavaj *et al.*, 2018). Stemming from pro-social information processing, perspective-taking in knowledge collaboration denotes the expectation that others' viewpoints could be different, which reduces the unease caused by different opinions and hence facilitates constructive management of the distinctions (Batson and Powell, 2003; Grant and Berry, 2011; Tjosvold and Deemer, 1980).

When involved in pro-socially motivated interactions, online crowd members can think thoroughly about others' beliefs and values and hence the reasoning and rationale behind others' representations of the problem. Eventually, the conflicts of opinion and representational gaps can be reduced, and collective performance can be improved (Adler and Chen, 2009, 2011; Xiao, 2014). In online open innovation, knowledge integration appears to be difficult to accomplish because of representational gaps as well as the lean social context faced by online crowds. Pro-socially motivated interaction may enable the diverse members of the online crowd to co-create solutions without having to negotiate too many details through the interactive commenting facility of the online platforms used (Boudreau and Lakhani, 2015; Sawyer and DeZutter, 2009). Baralou and Tsoukas (2015) demonstrated that when knowledge contributors engage in interactive commenting, they can compare the knowledge content contributed by others to their own knowledge, leading to changed minds or unexpected similarities to their causal models of the problem. Therefore, it may be possible that, when interactively commenting on others' knowledge, enough of common ground is created to overcome the negative impact of knowledge diversity. Our study, therefore, hypothesizes the role of pro-socially motivated interaction in mitigating the negative effect of knowledge diversity:

H3. Pro-socially motivated interaction moderates the relationship between knowledge diversity and the emergence of integrative ideas: the greater the level of pro-socially motivated interaction presented during a discussion thread, the more positive the relationship between knowledge diversity and the contribution of an integrated idea.

Methods

The analysis was conducted on an existing data source of all posts obtained from 10 open innovation challenges initiated by 10 different organizations, each with the objective to obtain innovative solutions to the problem they faced. The data set was organized by threads. The emergence of integrative ideas was measured by using systematic coding instructions to determine whether or not an idea is integrative. Knowledge diversity was measured with a machine learning algorithm for identifying distinct topics and topic distribution across texts. Pro-socially motivated interaction was calculated as the ratio between the number of times that crowd members take turns in a thread and the total number of posts in a thread occurring prior to each idea. A multi-level, mixed-effects logistic model was used to test the hypotheses.

Data source

Our sample contains 2,244 posts embedded in 747 threads across 10 open innovation challenges offered from the same platform (BrightIdea) following similar instructions. A total of 214 integrative ideas were posted. The 10 open innovation challenges were initiated by

10 different organizations and were run for a 7-to-10-day period. The open innovation crowds were set up similar to collaborative innovation challenges (Majchrzak and Malhotra, 2013). An organizational problem was broadcast to the public. The challenge problem for each organization was advertised on specially-selected list serves which had a focus similar to the challenge problem. Contributors were members of the public interested in the topic. To encourage knowledge sharing among crowd members, incentives of equal value were provided for those having the best ideas as judged by the organization offering the innovation challenge problem, as well as for collaborating by contributing knowledge other than ideas (equal points were allocated for all these activities and a continuously updated leaderboard was displayed on the crowd website). No one moderated during the challenge, with all contributors encouraged to use pseudonyms rather than their real names. There was no involvement of executives in the discussion threads. The instructions encouraged members of the crowd to start or respond in a discussion thread, by sharing their knowledge about the challenge problem, including ideas or other relevant knowledge they had.

Dependent variable: the emergence of integrated ideas

We analyzed all contributions posted in the 10 crowd-based open innovation challenges and coded whether or not a post included an integrated idea. Ideas were coded as integrated when the text explicitly referenced a prior post, such as "I think these two ideas can be combined" or "Building on the prior comment" (see Table 1 for further illustration). We used a 0–1 dichotomous coding which means that posts not containing any integrated ideas were rated with 0, and the others were rated with 1. Our coding demonstrates that 9.5% of posts across all open innovation challenges contained integrated ideas.

Independent variables

Knowledge diversity. We used a natural language processing approach to determine the diversity of knowledge presented in all posts that were already in the thread before a crowd member contributed. Specifically, we created a topic model for each of the 10 challenges based on Latent Dirichlet Allocation (Blei *et al.*, 2003), a Bayesian statistical technique looking at co-presence with other words in the same unit of text. This approach assumes

Table 1 Standalone idea vs integrated idea

Idea type	*Definition*	*Illustrative examples*
Stand-alone individual idea	Short idea statement that addresses some facet of the problem but does not integrate others' ideas or problem description knowledge	"Could we do it this way. . .," "I was thinking that maybe we could. . .." "I'd like to make a proposal."
Integrated idea	Statements that combined multiple ideas and/or problem description knowledge (others' facts, examples and tradeoffs) that form a comprehensive solution.	"In some cultures, ethics/values are taught at a young age (9yrs old) in school. [An earlier fact stated by another member]. That is boring and unbearable as a kid. Why not have these animated characters [another member's earlier idea] show us those values and teach kids at a young age some key values [. . .] This can be totally expanded to be an educational program! Similar to [Another member's name] educational idea with roles and responsibilities!" "Didn't see this before I posted my idea, but I think these [ideas] could be combined. To expand on it, some of the [company product names] could overlap, but others could likely be better as standalones so could sell multiple versions of these as long as they were compelling"

that a latent set of topics exists in texts and that any word appearing in the text will be attributed to one of these topics.

Using this technique, we indexed all 2,244 posts in our data set and generated a probabilistic topic model for each challenge that describes all posts as vectors of weights of latent topics. The results of this analysis allowed us to calculate the cosine distance between vectors representing different posts. Cosine distance, the angular distance between topic vectors, is a widely used measure for evaluating dissimilarity of texts (Deerwester *et al.*, 1990). This approach has also been adopted in scientometrics for measuring the similarity and dissimilarity of knowledge represented in documents (Landauer *et al.*, 1998).

Following this approach, we calculated the cosine distance for each pair of posts within a thread. Cosine distance is at the maximum of 1 if two topic vectors have no similarity at all and at the minimum of 0 if the two topic vectors fully overlap. Subsequently, we calculated our measure of knowledge diversity by taking the mean cosine distance between all posts that were already in the thread before a crowd member made her contribution.

Pro-socially motivated interaction. Our measure of knowledge contributors' pro-socially motivated interaction is based on the number of times that multiple crowd members take turns to communicate their perspectives in responding to prior posts. This operationalization is informed by the sequential model of conversation used in conversation analysis, which conceptualizes speaker-alternations that result in sequential production and understanding of talk (Sacks *et al.*, 1974; van Dijke, 1996). Accordingly, we analyzed the sequence of posts that had occurred in a thread before a member is making his or her contribution and counted the number of times that different contributors were taking turns to present perspectives, i.e. instances of two subsequent posts that were not submitted by the same contributor. To make our measure comparable for threads of different lengths, we created a normalized measure by dividing the number of turns by the total number of posts occurring in the thread before the idea was posted (Table 2). Highly interactive threads, in which all posts receive responses from other contributors have the maximum value of 1, indicating a high level of contributors' activeness in pro-socially motivated interaction. Threads that contain subsequent posts by the same contributor exhibit a lower ratio and will show the minimum value of 0 if no other contributors ever respond to any post in a thread, suggesting that no other contributors have actively participated in pro-socially motivated interaction. The level of pro-socially motivated interaction varies significantly between threads, with a mean value of 0.661 across the 10 open innovation challenges.

Table 2 Illustration of pro-socially motivated interaction measure

Low *Pro-socially motivated interaction*		*Medium* *Pro-socially motivated interaction*		*High* *Pro-socially motivated interaction*	
New turn	*Contributor*	*New turn*	*Contributor*	*New turn*	*Contributor*
	A		A		A
✓	B	✓	B	✓	B
–	B	✓	C	✓	C
–	B	–	C	✓	D
–	B	✓	B	✓	A
✓	C	–	B	✓	E
–	C	✓	D	–	E
✓	A	–	D	✓	C
–	A	✓	B	✓	E
		✓	D		
# Posts involving pro-socially motivated interaction: 3 out of 8 possible = 0.375		# Posts involving pro-socially motivated interaction: 6 out of 9 possible = 0.667		# Posts involving pro-socially motivated interaction: 7 out of 8 possible = 0.875	

Control variables

Prior contributors in thread. Size, i.e. the number of contributors has been shown to affect knowledge creation (Boudreau, 2012). We measured the number of prior contributors in the thread, at the time the idea was posted. The number ranged from 0 when an idea was posted as a top-level contribution (i.e. a post that starts a new thread so there are no prior contributors in that same thread) to 10 prior contributors in the most extensive threads. 69.5% of all posts were made subsequent to prior contributors present in the thread, i.e. they offered the potential for pro-socially motivated interaction to occur.

Central phase. Participation in open innovation crowds can vary across different phases of the challenge event. In particular, it can take quite some time during the initial phase after launching an open innovation challenge for the crowd to gain momentum (Dahlander and Piezunka, 2014), making it less likely to exhibit discussion threads that may lead to useful ideas. On the other hand, toward the end of such a time-bound initiative, the potential for finding additional useful ideas may decline because of exhaustion of potential combinations and refinement (Fleming, 2001). The period in the middle phase may then be the "sweet spot" for creating helpful solutions. To control for any possible effects, we used a k-means clustering algorithm to identify for each challenge the length of time that each phase lasted. If a post was made during the central or middle time cluster, we coded it as 1, otherwise with 0.

Prior integrated ideas by contributor. Some members of the crowd may be more likely to create integrated ideas than others, for example, because they have a greater ability to associate ideas across multiple domains (Koestler, 1964), or because they have learned to build upon other contributors' knowledge in previous interactions. We use a proxy of 1 when the contributor previously offered integrative posts during the challenge; otherwise, the variable was set to 0.

Unfamiliar contributor. Crowd members who have contributed to a thread for some time may have developed some familiarity and common ground with other members participating in the thread, thus making it easier for them to synthesize knowledge into ideas (Harvey, 2014). Unfamiliar contributors, by contrast, may find it more difficult to synthesize various contributions into a potential idea. We control for this possible effect by coding whether a contributor who contributed the integrated idea is new to the thread (unfamiliar contributor = 1) or not (familiar contributor = 0).

Tables 3 and 4 present descriptive statistics and bivariate correlations for our variables.

Analysis approach

In our empirical analysis, we considered individual posts within a thread as our main level of analysis. We analyzed 2,244 posts embedded in 747 threads, which in turn are part of the 10 open innovation challenges. Our primary interest was to understand whether or not knowledge

Table 3 Descriptive statistics

	Mean	*SD*	*Minimum*	*Maximum*
Continues variables				
Knowledge diversity	0.070	0.100	0	01
Pro-socially motivated interaction	0.661	0.449	0	01
Prior contributors in thread	1.790	1.905	0	10
Categorical variables	(%)			
Integration	09.5			
Central phase	25.2			
Prior integrated ideas by contributor	41.1			
Unfamiliar contributor	22.6			

Table 4 Correlation matrix

Variables	*Integration*	*Knowledge diversity*	*Pro-socially motivated interaction*	*Prior contributors in thread*	*Central phase*	*Prior integrated ideas by contributor*
Knowledge diversity	−0.028***					
Pro-socially motivated interaction	−0.005***	0.368***				
Prior contributors in thread	−0.003***	0.530***	0.554***			
Central phase	−0.072***	0.013***	0.005***	0.066***		
Prior integrated ideas by contributor	−0.160***	0.142***	0.174***	0.157***	−0.004***	
Unfamiliar contributor	−0.021***	0.341***	0.254***	0.480***	−0.061***	0.277***

Notes: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

diversity has a negative effect on the emergence of knowledge synthesis, and whether or not pro-socially motivated interaction inverts the negative diversity–integration relationship.

To account for the hierarchical nature of our data, we used a multilevel mixed-effects model. This approach allowed us to model that multiple posts are nested within the same thread, potentially resulting in multiple integrated ideas; multiple threads, in turn, are nested within open innovation challenges. Our model uses random intercepts to account for possible differences in the level of threads and open innovation challenges, whereas our predictors are modeled as fixed effects on the level of individual posts. We applied logistic regression as the analysis approach carried out in STATA 16.

Results

Effect of knowledge diversity on knowledge integration

To test *H1*, we examined the effect of knowledge diversity on the emergence of integrated ideas (Table 5). We first specified a baseline model including control variables only to

Table 5 Effects of knowledge diversity and pro-socially motivated interaction on whether the idea is integrated

Dependent variable	*Knowledge integration* *Model 1*	*Model 2*	*Model 3*
Fixed effects			
Independent variables			
Knowledge diversity		−0.171*** − (0.046)	−0.570*** − (0.088)
Pro-socially motivated interaction		0.049 (0.277)	0.647*** (0.211)
Knowledge diversity × Pro-socially motivated interaction			0.714*** (0.141)
Control variables			
Prior contributors in thread	0.078 (0.116)	0.134* (0.053)	0.206*** (0.053)
Central phase	0.446** (0.165)	0.449** (0.167)	0.455** (0.164)
Prior integrated ideas by contributor	0.315 (0.206)	0.317 (0.175)	0.332 (0.182)
Unfamiliar contributor	−0.837*** − (0.243)	−0.797*** − (0.204)	−0.706*** − (0.193)
Intercept	−3.919*** − (0.545)	−3.949*** − (0.554)	−4.332*** − (0.502)
Random effects			
Intercept crowd (variance)	1.790 (1.072)	1.797 (1.055)	1.760 (1.019)
Intercept threads (variance)	0.415 (0.156)	0.445 (0.159)	0.520 (0.151)
N	2,244	2,244	2,244
Log-likelihood	−595.306−	−594.019−	−586.306
df	7	9	9
Akaike Inf. Crit.	1204.611	1206.037	1190.611
Bayesian Inf. Crit.	1244.623	1257.481	1242.055

Notes: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

assess the presence of random effects across open innovation crowds and threads (Model 1). Our results show that considerable variance can be attributed to random intercepts and that our choice of a mixed-effects model is appropriate. Our results in Model 2 indicate a significant and negative effect of knowledge diversity ($\beta = -0.171$; SE = 0.046; $p < 0.001$), providing support for *H1*. One standard deviation increase in knowledge diversity reduces the predicted emergence of integrated ideas by half a point on our scale.

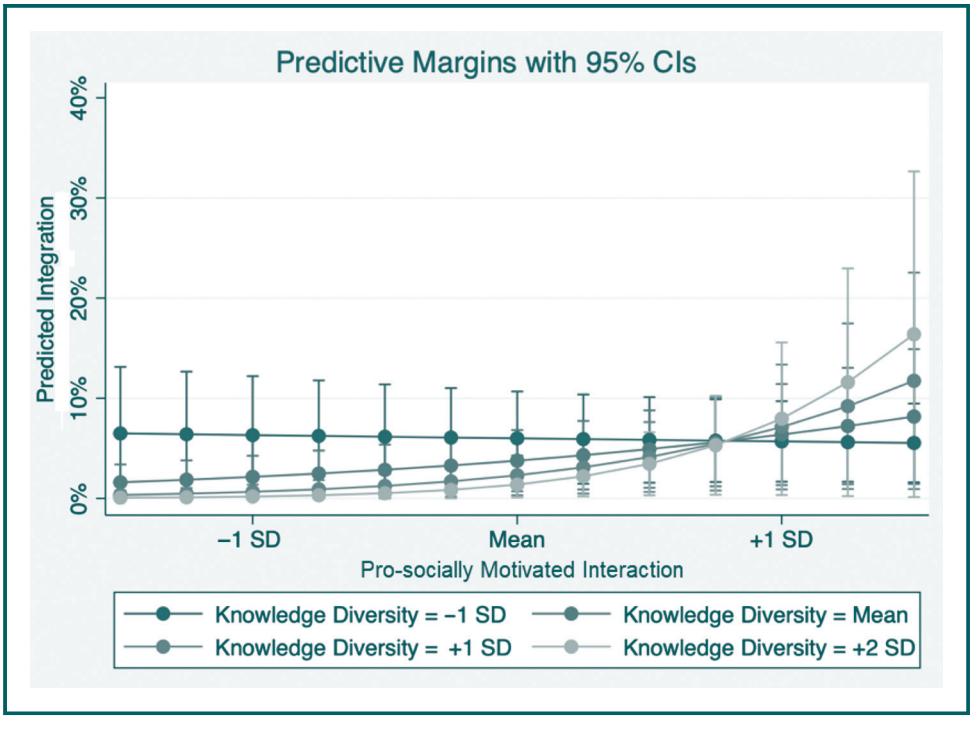
Moderating effect of pro-socially motivated interaction on diversity-integration relationship

To test *H2*, we examined the effect of pro-socially motivated interaction on the relationship between knowledge diversity and the emergence of integrated ideas. In Model 3, we introduced an interaction term between knowledge diversity and pro-socially motivated interaction.

Introducing the interaction effect resulted in a significant main effect of pro-socially motivated interaction ($\beta = 0.647$; SE = 0.211; $p < 0.01$). This suggests that at a mean level of knowledge diversity, an increase in contributors' pro-socially motivated interaction is likely to result in a higher likelihood of the emergence of integrated ideas. The significant main negative effect of knowledge diversity ($\beta = -0.570$; SE = 0.088; $p < 0.001$) was also replicated.

Finally, the interaction term of knowledge diversity-by-motivated interaction is statistically significant with a positive coefficient ($\beta = 0.714$; SE = 0.141; $p < 0.001$). This result provides evidence in support of our moderation hypothesis that, at higher levels of pro-socially motivated interaction, the negative relationship between knowledge diversity and the contribution of integrated ideas is inverted. Figure 1 provides a two-way interaction plot to offer a more nuanced interpretation of this moderation effect. Figure 1 suggests that at

Figure 1 Two-way interaction plot of knowledge diversity and pro-socially motivated interaction on whether the idea is integrated



very low levels of knowledge diversity (1 SD below mean), a change in pro-socially motivated interaction has virtually no effect on the contribution of integrated ideas. At mean levels of knowledge diversity, however, any increase in pro-socially motivated interaction increases the likelihood that an individual contributes an integrated idea. At very high levels, pro-socially motivated interaction is not just attenuating the negative effect of knowledge diversity on the contribution of integrated ideas, but actually results in the inversion of the negative relationship.

Discussion

As innovation is increasingly generated by harnessing the wisdom of the crowd (Chesbrough, 2003; Leimeister *et al.*, 2009; Surowiecki, 2005), many studies have investigated the value of knowledge sharing in social computing and crowdsourcing (Schenk and Guittard, 2011). More and more innovation challenges require solving broadly defined problems that are characterized by interdependent and non-decomposable elements and, therefore, may be better solved by pro-socially motivated interaction that facilitates the integration of multiple perspectives of the crowd members (Buchanan, 1992; Harvey, 2014; Pacanowsky, 1995). In other words, to successfully co-create solutions, the crowd should not only interact and share knowledge but also integrate the knowledge they share (Malhotra and Majchrzak, 2014). However, thus far little is known about how knowledge is synthesized in online crowds' knowledge co-creation for innovation. In this regard, the present research examines the dynamic of online crowds' knowledge integration, seeking to understand the conditions under which members of the temporary online crowd are able to collectively generate integrative solutions to open innovation challenges. Our current study aims at presenting theoretical and empirical explanations of the circumstance under which members of the crowd can produce knowledge integrations in response to open innovation challenges.

Our research focuses on how crowd members engage in pro-socially motivated interaction to understand the diverse knowledge shared by others and thus recognize opportunities for synthesizing individual knowledge into integrated ideas, and it makes both theoretical and practical contributions. Theoretically, our contribution lies at suggesting the mitigating role of pro-socially motivated interaction in the negative relationship between knowledge diversity and knowledge integration. We extend the literature on crowd-based open innovation by suggesting the important role of perspective-taking, a pattern of pro-socially motivated interaction that evolved organically in some threads and not others. In online contexts like open innovation crowds, when the members are not familiar with each other and lack the opportunity to develop common ground (Hwang *et al.*, 2015), the emergence of such kind of pro-socially motivated interaction facilitates a collective understanding of how the various contributions might relate to one another so that it enables individuals to iteratively generate and share ideas based on their own specialized expertise (Tiwana and McLean, 2005).

The first implication of our research comes from our focus on knowledge integration. Integration among open innovation crowds is particularly important because many of the problems that crowds are asked to solve require multiple perspectives (Nickerson and Sakamoto, 2010); the more comprehensively these perspectives are integrated, the more likely that the solution is one which, if implemented, will have a substantial impact in alleviating the problem (Nickerson and Sakamoto, 2010). Moreover, to the extent that crowd members also include employees responsible for the implementation of solutions – such is the case in open innovation crowds in the context of internal organizational challenges – having integrated ideas representing others' perspectives are more likely to produce significant benefits to the organization (Stieger *et al.*, 2012). Future research should continue this path to examine not simply the quality of an idea but how well it integrates others' perspectives.

Second, in online crowds, a coordination mechanism may organically emerge that is able to productively generate integrated ideas, similar to the organizational coordination mechanisms that typically facilitate knowledge integration (Galbraith, 1977; Grant, 1996) and implicit coordination documented in off-line group collaboration contexts (Faraj and Xiao, 2006; Majchrzak *et al.*, 2012). We show that this organically emergent mechanism seems to play a role in mitigating the negative effect of knowledge diversity on the emergence of knowledge integration. We theorize the reason for this effect is that, as members of the online crowd organically engage in pro-socially motivated interaction, it increases their ability to close their representational gaps, reduce conflicts of opinion and ultimately produce more integrated ideas. Being able to comprehensively understand others' perspectives offers the opportunity to obtain and absorb useful information from others (Füller *et al.*, 2014), as well as the opportunity for a norm of knowledge sharing to develop among strangers (Wasko and Faraj, 2000). Meanwhile, our finding that pro-socially motivated interaction facilitates the generation of integrated ideas offers suggestions for follow-on research. Future research could examine alternative possible explanations to such mechanism, for example, in very large and active crowds, the members' pro-socially motivated interaction for reflection may easily lead to information overload and the feedback provided by others is likely to be inconsistent providing little value for integration. In such a context, the explanation that pro-socially motivated interaction creates shared norms may be more powerful than the other explanations. In smaller crowds, by contrast, the role that pro-socially motivated interaction plays for reflection may be the more powerful explanation. Future research should assess, then, not just the different socio-cognitive mechanisms, but also which types of crowds each mechanism applies.

Our study further suggests the important role of knowledge sharing through demonstrating the positive effect of pro-socially motivated interaction. If collaborators are able to take others' perspectives and think thoroughly about others' reasonings and rationales, they are better able to understand and incorporate others' meaning into their own ideas (Hoever *et al.*, 2012; De Dreu *et al.*, 2000). Majchrzak and Malhotra (2016) describe many different knowledge sharing patterns in open innovation crowds, indicating that many of them involve little to no knowledge sharing. Our findings suggest that these alternative patterns may not be profiting from the crowd as much as they could. Future research should consider experiments incorporating pro-socially motivated interaction into open innovation crowds with different knowledge sharing patterns to assess the generalizability of this effect.

Meanwhile, the negative effect of knowledge diversity calls into question earlier findings about the positive role of diversity. As theorized, as members of the online crowd contribute diverse knowledge, representational gaps may occur and then impede collective information processing (Cronin and Weingart, 2007). In online open challenges where members of the crowd may not have existing shared social relations, representational gaps will result in misunderstandings as well as a lack of common ground for communication (Faraj *et al.*, 2011; Viscusi and Tucci, 2018), so that knowledge collaborators tend to generate less knowledge integration. It has been argued in previous research that expertise diversity (i.e. high specialization among team members) has a positive effect (Füller *et al.*, 2017; Schenk and Guittard, 2011); however, if the diversity of experts leads to more knowledge diversity in contributions and less pro-socially motivated interaction at the same time, chances of harnessing the potential may be reduced. As such, prior studies on the impact of demographic and expertise diversity on innovation outcomes in crowds need to be reconsidered (Dahan and Mendelson, 2001; Robert and Romero, 2017; Terwiesch and Ulrich, 2009). Exploring the relationship between knowledge diversity and other forms of diversity is also needed, and the assumption that diversity in background or expertise translates to knowledge diversity should be carefully considered.

Finally, our innovation crowdsourcing challenges asked crowds to solve ill-structured problems. On the one hand, several researchers have argued that crowds cannot solve

ill-structured problems because they do not have enough tacit knowledge about the problem, they are unlikely to effectively share their knowledge with others, they are unlikely to see all aspects of the systemic problem and understand the interdependencies and they are unwilling to spend the time and effort it might take to generate useful innovative solutions to systemic problems (Afuah and Tucci, 2012; Henkel *et al.*, 2014; Lakhani *et al.*, 2013). These researchers, consequently, have suggested that innovation crowdsourcing challenges should be limited to well-structured problems with clear evaluation criteria, well-defined constraints, and specific parameters to consider and ignore; other forms of external relationships such as joint ventures are better suited for ill-structured problems. An entire industry of organizational intermediaries (e.g. Innocentive, Nine Sigma, Bright Ideas) has evolved to help organizations craft crowdsourcing problems to be sufficiently well-structured to be amenable to crowdsourcing (Lopez-Vega *et al.*, 2016). On the other hand, in contrast to this negative assessment of the value of crowds for ill-structured problem-solving, other researchers have argued that crowds are able to collectively produce innovative solutions (Hautz *et al.*, 2017; Nickerson *et al.*, 2017; Viscusi and Tucci, 2018).

Our research provides a possible resolution to this conundrum of when to use the crowd for problem-solving. Our research suggests that ill-structured tasks can be given to crowds, with integrative and innovative ideas generated in return – provided that the crowd engages in pro-socially motivated interaction as the way in which they collectively create knowledge. In other words, the debate no longer needs to be about whether crowds should or should not be exposed to ill-structured tasks as it was during the earlier literature on the use of crowds for innovative problem-solving. Rather, future research will benefit from examining the various socially motivated interaction options made possible through ubiquitous access to a publicly-available information and communications technology (ICT) and learning which ones most effectively yield innovative outcomes. Then, the social interaction option that appears most effective for crowds should be compared with current approaches to solve ill-structured problems, such as internal top management teams and joint ventures (Poetz and Schreier, 2012). At that point, then, theorizing may be able to more appropriately address the question of when it is best to use a crowd.

Implications for managerial practice

In addition to being of theoretical interest, our findings shed light on the practice of knowledge collaboration and crowd-based open innovation. Prior suggestions for the design of crowdsourcing and other open innovation to increase the probability of the emergence of innovative ideas focus on manipulating the levels of knowledge diversity by engineering the composition of crowd members (Afuah and Tucci, 2012; Boudreau and Lakhani, 2009; Füller *et al.*, 2014). We suggest, however, that simply increasing the knowledge diversity may not be enough, particularly when the problems being solved are ill-structured, such as strategic formulations. Instead, the diversity needs to be coupled with encouragements for crowd members to find a discussion thread they are interested in, and then actively take others' perspectives during pro-socially motivated interaction. In other words, our contribution to research on open innovation is to identify pro-socially motivated interaction as a specific mechanism of knowledge integration.

To motivate online crowds to engage in more pro-social interactions, open innovation challenge platforms should be designed in a way that incorporates various kinds of incentives, as the information system not only acts as an enabler but also is shaping the open innovation outcomes (Majchrzak and Malhotra, 2013). In this regard, using different incentives appropriately and strategically will be the key to encouraging crowd members' pro-social interaction (Boudreau *et al.*, 2011; Boudreau and Lakhani, 2015; Lakhani, 2016).

Limitations

This study is limited in several ways and thus sets the stage for future research. First, we analyzed texts from open innovation challenges without discerning the industry sector or other environmental and market contexts. As such, we do not know how idea integration is affected by contextual conditions. We also did not have data on crowd members' industry experience and expertise and therefore do not know how that would affect the relationships we found.

Another limitation relates to the potential effects of individual-level behavioral differences such as creative capacity or individual personality – as has been the focus of substantial previous research on crowdsourcing for innovation (Bullinger *et al.*, 2010; Ebner *et al.*, 2009). We did not study crowd members' individual behavioral characteristics in this research. Further research is needed that combines both the knowledge-sharing behaviors and individual characteristic differences.

Finally, incentives should be explored. Should the crowd members be encouraged to form ad-hoc groups that are focused on integration or be given a more direct incentive for producing integrative ideas after the early phase of discussion so as to avoid membership turnover remains open for future research.

Conclusion

Crowd-based open innovation is increasingly used by firms to generate innovative ideas for new products, processes, services, and business models. It is important to consider the role of knowledge diversity in these open innovation crowds. We examine the relationship between knowledge diversity and the emergence of knowledge integration and find it to be negative. Open innovation crowds can overcome this negative relationship by actively engaging in pro-socially motivated interaction.

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