Understanding the Emergence of Collaborative Problem-Solving Practices in Enterprise Social Media: The Roles of Social Factors

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ABSTRACT Firms are increasingly introducing enterprise social media (ESM) technologies to nurture the virtual community of practice, offering a prospect for collaborative problem-solving (CPS) within organizations. Based on a unique dataset including 10101 actual problem-solving scenarios across 519 ESM groups, our objective is to identify the relationships between many social factors and the occurrence of CPS by drawing on different social theories. Via multilevel logistic regression, we found that the quality and decentralized degree of social interactions in an ESM group can increase the likelihood of CPS; one user's social similarity with other members of the group and the user's user classes are positively related to the likelihood of CPS. Finally, social ties' strength between the user and other members in the ESM group has a U-shaped association with the likelihood of CPS. These findings can provide companies with meaningful implications for using ESM sites to support CPS.

INDEX TERMS Collaborative problem-solving, enterprise social media, virtual group, social influence, multilevel logistic modeling.

I. INTRODUCTION

As knowledge is treated as a strategic resource, a knowledge-based view of organizations has emphasized the importance of knowledge exchange and collaboration for employees' problem-solving [1]. Collaboration is necessary for problem-solving not only because individuals are often unable to solve their problems efficiently and effectively but also because the interactions of a collective can yield creative insights and good ideas [2], [3]. However, collaborative problem-solving (CPS) needs employees to develop mutual understanding, trust, and consequently identity [4]. The perspective of the community of practice has pointed out that work practices involve mutual engagement among employees by cohering to an informal and situated group (i.e., community) [5], [6].

According to this perspective, collaboration is often not planned but rather emerges within organizations [7], [8]. It is generally agreed that social forces can play crucial roles

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in promoting such moments of problem-solving. Employees build work and friend ties as sources of information and collaboration, which makes progress on relatively short-term and unique problem-solving [9], [10]. Employees' social status and attitude similarity with others also affect the emergence of CPS [11].

Over the past decades, scholarship in the field of information systems has focused on the electronic community where users without offline contacts participate in each other's problem-solving practices [12]–[14]. More recently, many large companies have updated their internal technologies from traditional tools (e.g., e-mail) to social media tools (e.g., microblogging) [15]. Leonardi and his colleagues termed the new phenomenon enterprise social media (ESM) and found that ESM can promote emergent practices of knowledge collaboration by increasing the visibility of the network and content [16]–[22]. Against this background, ESM is expected to become an active place for CPS through establishing a virtual community of practice within organizations [23]–[28]. How CPS emerges in ESM communities becomes an open question.

Therefore, the study aims to contribute to the important issue by identifying the relationships between a number of social factors and the emerging of CPS in ESM communities. By analyzing a unique dataset collected from the internal ESM site of a knowledge-intensive company, we captured the actual scenarios of problem-solving and measured these social factors. Therefore, this study involves social factors not only at the level of problem-solving scenarios but also at the level of groups where these problem-solving scenarios occur. Based on a sample including 10101 problem-solving scenarios embedded in 519 ESM groups, we used a multilevel logistic modeling strategy to test the hypothesized relationships.

These efforts can contribute to the literature and practices on ESM and CPS in organizations. First, the study adds new insights to the literature on ESM. Recently, many ESM studies investigated the enablers of ESM usage for knowledge sharing. However, the existing literature mainly used a survey method to examine employees' self-reported factors and behaviors related to knowledge [27], [28]. Instead, our study focuses on actual knowledge-related practices in virtual groups enabled by ESM communities. We also empirically showed that collaborative practices in ESM communities have a social nature, which has been extensively argued by researchers of ESM [20], [21]. Second, the present study also sheds a light on the black box of CPS within organizations. Although the prior organizational literature provides several qualitative studies, quantitative relations among social factors and CPS have rarely been examined [3], [8]. Considering that organizations are increasingly becoming virtual, our study recommends that organizational researchers and designers understand the processes of collaboration in an online context within organizations. Specifically, the empirical findings in the study suggest that the social features of problem-related objects and virtual groups to which these objects belong should be considered for promoting collaboration.

The remaining sections of this article are as follows. Section 2 conducts a narrative literature review of related works. The theories and hypotheses are illustrated in Section 3. In Section 4, the research method is presented in detail. Section 5 describes the main data analysis process and results. Discussions on the empirical results from Section 5 are conducted in Section 6. Finally, Section 7 concludes the paper.

II. LITERATURE REVIEW

A. PROBLEM-SOLVING IN ORGANIZATIONS

Problem-solving involves processes inside and outside the mind. For the processes inside individuals' minds, psychological scientists have proposed many cyclical models [29]. For example, Davidson and Sternberg [30] described problem-solving as a cycle, including problem identifying and defining, strategy developing, knowledge organizing, mental resources allocating, progress checking, and

adjustment testing. Although these models underline internal mental representations of problems, it is agreed that resources outside the mind become the basis for internal processes of an individual's problem-solving. Starling [31] treated problem-solving as a social process through which solvers seek information from the social environment and collaborate to solve their problems. Therefore, problem-solving involves the application of both cognitive skills and social skills [32].

Work practices consist of consecutive episodes of problem-solving [8]. The importance of knowledge exchange and collaboration for problem-solving has been emphasized by the knowledge-based view [1]. Hargadon and Bechky [2] argued that the need for individual creative genius is steadily being displaced in organizations. Due to these potential values, it is crucial to understand how CPS is being achieved within organizations.

It is common in the execution of day-to-day work routines that employees often encounter unpredictable and personalized problems and need potential collaborators to provide help dynamically. In a three-year ethnographic study of problem-solving activities in a high-tech company, Mangrum *et al.* [8] found that problem-solving is more often "handled in informal and spontaneous gatherings of workers rather than in formal meetings or by other formal methods" (p.316). Informal CPS is not included in organizational reward systems [33]. The perspective of the community of practice argued that employees build informal and situated groups where work practices are mutual engagement based on mutual understanding, trust, and identity [5], [6]. Therefore, CPS is often not planned but rather emerges within organizations [7].

For the emergence of such collaborative moments for problem-solving, research tends to highlight the role of social factors rather than institutional factors. From the standpoint of a solver, the social relationships or networks the solver built will impact the likelihood of others engaging in his/her problem-solving [9]. Cross and Sproull [10] found that employees cultivate different types of information relationships, which can lead knowledge to action. A solver is also more likely to seek collaboration with persons who are similar or socially connected with the solver rather than from those who were best equipped to correct the problem [7]. The position of brokers is more likely to enable their problem-solving to be engaged [34]. The emergence of knowledge transfer also requires employees to develop a shared understanding with others through consecutive social interactions [35].

However, most of these studies tend to endorse the value of abstract behavior over actual practices, so the emergence of CPS is still a black box to a considerable degree [8]. For example, Mangrum *et al.* [8] used an inductive interpretation of the phenomenon of how informal problem-solving is accomplished within organizations. Different from these studies, we examined actual problem-solving practices, which are difficult to be captured and recorded in daily work [2], [7], at an ESM site. It is more difficult to keep the context of these problems completely in face-to-face work.

Today, employees use ESM or other digital sites to build an intraorganizational virtual community of practice so that problem-solving practices at the sites can be recorded in a digital way [36].

B. ESM

In line with the perspective of the community of practice, public social media sites and online communities have been continuously examined in the past two decades. The scholarship has shown that online communities are noteworthy spaces for knowledge collaboration. Within organizations, the virtual community of practice can be supported by using information technology [37]. Because of the social nature of online communities, it is no surprise that social forces can play a crucial role in driving the emergence of CPS [38]. For example, Wu and Deng [39] evidenced that in an online healthcare community, leaders' social capital promotes members' coordination behavior; additionally, a study by Moqri *et al.* [14] showed that in open-source software communities, obtaining new followers in the previous month has a significant positive effect on developers' level of contribution in the current month. For online communities within organizations, Wasko and Faraj [40] indicated that employees contribute knowledge to electronic networks when they perceive that it enhances their reputation and when they are structurally embedded in the network.

Recently, an increasing number of companies have updated internal technologies from traditional tools (e.g., e-mail) to social media tools (e.g., microblogging), intending to further enhance knowledge exchange across the entire organization [15]. Leonardi and his colleagues termed the new phenomenon ESM [17]. According to Bulgurcu *et al.* [25], ESM refers to proprietary social media technologies that are used within the closed boundaries of an organization. Researchers have expected the benefits of ESM for CPS because they believe that ESM can nurture a virtual community of practice within organizations [23], [41]. In turn, the emergence of CPS is also a signal of ESM effectiveness.

Against this background, how CPS emerges in ESM communities becomes an open question. According to Leonardi and his colleagues, ESM provides users with different affordances (e.g., visibility, editability, persistence, and association) and increases the likelihood of knowledge collaboration and exchange [16]–[22]. For example, the visibility affordance of ESM can enable the ambient awareness of the knowledge environment, which in turn helps users to locate potential collaborators [20]. Further empirical studies evidenced that ESM affordances promote knowledge transfer behavior [42], enhance the formation of social ties [43], and decrease perceived knowledge code efforts [44]. Additionally, research using survey data has investigated the associations between a number of social factors (e.g., reputation) and individuals' intention, attitude, and behavior to collaborate and share knowledge [45]–[47]. For example, Iglesias-Pradas *et al.* [46] demonstrated that both trust and shared goals have positive relationships with employees'

intention to use ESM to collaborate with other users. Aboelmaged [45] found that employees have the hedonic motivation to adopt ESM tools for sharing knowledge with others. In fact, these studies did not break through the traditional perspective of collaboration, that is, a perspective of individuals. Unlike these studies, the present study considers actual collaboration practices in ESM communities, which include the process of individuals' decisions. However, our study can surpass the onefold view of collaboration. Another unique feature of our research compared with prior studies is that we can use actual data rather than self-reported data.

As exceptions, two studies used actual digital data to examine the emerging of knowledge interactions among ESM users. Based on actual digital data from an ESM site used at Deloitte Australia, Riemer *et al.* [48] found that a user's position in the organization's hierarchy and a user's contributions on the site influence the timeliness of responses from other users. Another study by Beck *et al.* [24] suggested that social presence, social contribution, social relationship, and social similarity have effects on the quality of knowledge flowing through dyadic interactions between knowledge seekers and contributors. Similarly, our study has access to the internal ESM site of an online game firm. Digital records of users' activities enable us to identify the associations between a number of social factors (see the following section) and the emergence of actual CPS at the site.

Due to the collaborative nature of ESM, the extant literature has argued that ESM has proliferated to encourage teamwork in organizational settings [41]. The virtual group is one of the main functions for ESM to support such teamwork [46]. For example, in the company of Deloitte Australia, employees used an internal ESM platform to create and join network-based groups. Against this general backdrop, the present study focuses on group-based problem-solving in ESM communities rather than other places. Figure 1 indicates the hierarchy of group-based problem-solving scenarios in ESM communities. First, a problem-solving scenario includes a concrete problem, a poster of the problem, potential collaborators (or solvers except for the poster), and the social context that these elements have (e.g., group). In ESM communities, there are different types of problem-solving scenarios. For example, in enterprise microblogging, one user blogs or posts a problem, and then, other users (strangers or followers) can see it and comment. In the present study, we focus on problem-solving scenarios in ESM groups. The recent ESM literature has pointed out that virtual groups are the main space where employees use ESM to solve problems [23], [48]. Second, a problem-solving scenario exclusively belongs to an ESM group. That is, the factors at the group level may affect the occurrence of CPS in that specific group.

III. THEORIES AND HYPOTHESES
A. SOCIAL INTERACTIONS AT THE GROUP LEVEL
Generally, social interactions at the group level refer to multipoint communication among members [49], [50].
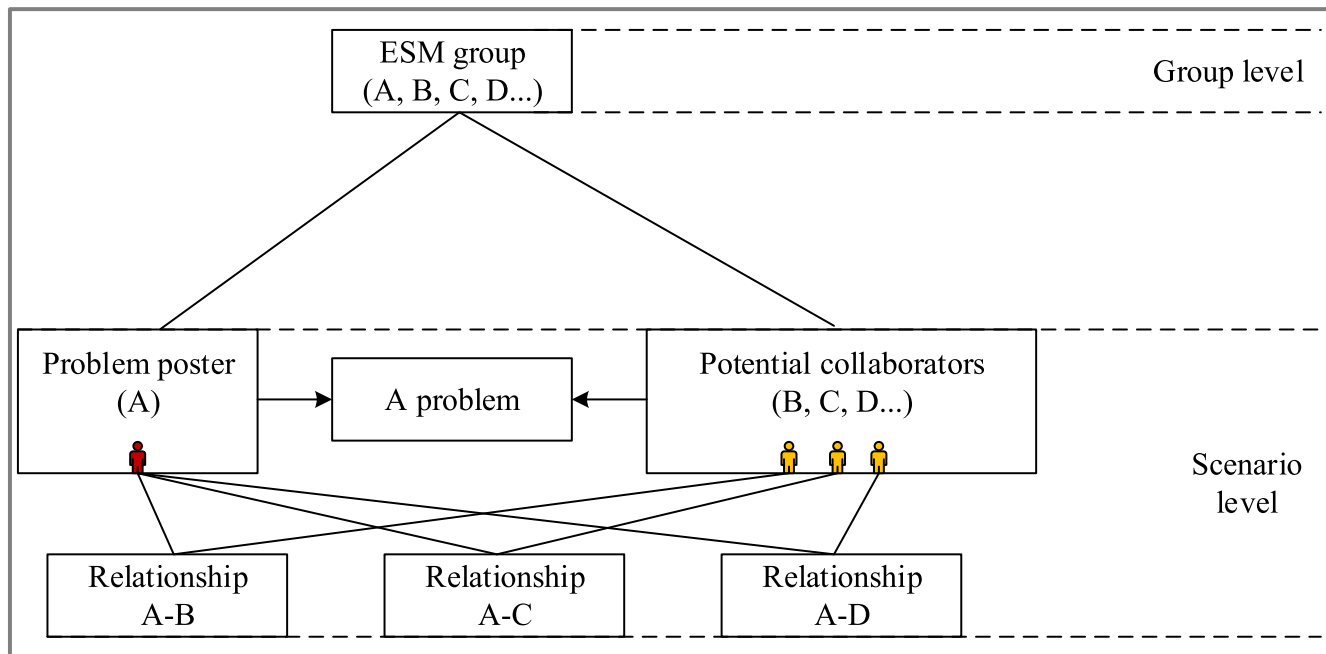
FIGURE 1. Hierarchy of group-based problem-solving in ESM communities.

Theories of group processes have argued that social interactions are processes in and of themselves because they depict the nature of member interactions [51], [52]. Marks *et al.* [51] pointed out that interpersonal interactions occur throughout all phases and lay the foundation for the effectiveness of other processes. Specifically, social interactions can strengthen members' participation by diffusing information, nurturing cohesion or trust, building relationships, and forming other social influence [53]. For virtual groups, content and structure features of social interactions can affect members' participation [49], [54], [55]. Due to that information, expertise, and experience are located in each member's mind, and social interaction quantity and quality are crucial to influencing members' behavior. According to Mcguire *et al.* [56], more sufficient social interactions can reduce misunderstandings and enhance coherence, which in turn increases the likelihood that members help each other. However, computer-mediated communication lacks social context cues [57]. Therefore, increasing the quality of members' communication will further promote members' engagement [58], [59]. Therefore, we posed the following two hypotheses in terms of the content feature of social interactions among members of ESM groups.

H1a: Problem-solving is more likely to be engaged in groups with a greater number of social interactions.

H1b: Problem-solving is more likely to be engaged in groups with a higher quality of social interactions.

Distinguishing with the content feature, the structure feature of social interactions reflects the distribution of information across the group members [60], [61]. For the structure feature, research has shown that centralized structure tends to make ordinary members experience lower empowerment, cohesion, trust, and a sense of belonging [62]. Although establishing or joining ESM groups is of one's own accord, members in centralized groups may feel they are marginalized, which may decrease their intention to participate. Becker and Baloff [63] argued that centralization may lead to production blocking of idea generation and information gathering and decrease the flexibility of decision making. Therefore, the following hypothesis in terms of the structure feature of social interactions is posed.

H1c: Problem-solving is less likely to be engaged in groups with a higher centralization degree of social interactions.

B. SOCIAL SIMILARITY AT THE GROUP AND SCENARIO LEVEL

Sociologists use the term ''homophily'' to describe the phenomenon that people tend to interact with others who are similar to themselves [64]. Social similarity represents the degree to which people are similar in terms of certain attributes, such as gender, race, and position [24]. Similar persons attract each other because they are more likely to possess opinions and interests, nurture trust, and have enjoyable interactions, thus smoothing the coordination of joint activities [24]. A recent study by Irving *et al.* [65] showed that geographical proximity can harmonize the differences between members and increase the chance of serendipitous encounters and interactions. Similarity in terms of other individual attributes (e.g., gender and hierarchical rank) can lead to spontaneous collaboration [9], [66]–[68]. According to Tsui *et al.* [69], such similarities are associated with higher levels of psychological attachment among groups, which in turn promotes members' engagement in group processes. Scholars in the information

systems field also found that social similarity has positive effects on users' collaboration in online communities [24]. In the context of our study, social similarity may function at both the group and scenario levels. A group may consist of members with different social attributes so that the likelihood of CPS in different groups is different. Additionally, the similarity between a poster and potential collaborators in a specific group is related to the likelihood of CPS. Accordingly, we posed the following two hypotheses.

H2a: Problem-solving is more likely to be engaged in groups whose members have a higher social similarity.

H2b: In a specific group, problem-solving by a poster who has a higher social similarity with other members of the group is more likely to be engaged.

C. SOCIAL RELATIONSHIPS AT THE SCENARIO LEVEL

Social network theory argues that individuals develop and maintain social relationships with others, which become crucial bases of behavior. Information scientists have evidenced that network features (e.g., types, structures, and positions) have important impacts on collaborative action and the emergence of collaborative practices [24], [70], [71]. Our study focused on the social ties' strength between a poster and potential collaborators, the most often used concept for evaluating social relationships in the literature. Social ties' strength represents "the strength of relationships, the amount of time spent on interaction, and the frequency of communication among members" (p. 828) [72].

Research has distinguished individuals' social ties between weak types and strong types [73]. Weak ties are beneficial because they provide new and diverse information but poor emotional support and expected reciprocity, whereas strong ties offer emotional support and expected reciprocity but redundant information [74], [75]. Considering different values, people have different mental models in maintaining these social ties. Although the number of weak ties is beneficial, the strength of weak ties makes one's maintenance costs increase [12]. For strong ties, people would like to invest time and effort to enhance them to obtain personal benefits such as word-of-mouth and expected reciprocity (e.g., emotional support) [9]. In our study, we argue that there is a critical point in the continuum of social ties strength between a poster and potential collaborators [76]. Before reaching the point, a weak type of social ties is formed, and the potential collaborators' motivation for engaging in the poster's problem-solving will dwindle gradually as the strength increases because the costs of maintaining weak ties with higher strength will increase sharply. After reaching the peak, a strong type of social ties begins to function, and the potential collaborators are more likely to participate in the posters' problem-solving as the strength increases because they want to maintain or enhance the relationship and improve reciprocal benefits. Accordingly, we proposed the following hypothesis.

H3: In a specific group, the strength of social ties between a poster and other members of the group has a U-shaped association with the likelihood that the poster's problem-solving is engaged.

D. SOCIAL STATUS OF POSTERS AT THE SCENARIO LEVEL

Social status accrues for people who employ apparent possession of attributes valued by other members of their social group [77]. Social role theory indicates that people with lower social status are attracted to persons who have a higher social status because they have a higher reputation, social influence, power, and ability [11]. This is partly because people with higher social status are more likely to offer valued information and resources. From the standpoint of potential collaborators in ESM groups, engaging in problem-solving by posters with higher social status may not only improve their positions but also boost their self-esteem and self-recognition [78], [79]. Therefore, we argue that in a specific group, members are more likely to engage in problem-solving by a poster with a higher social status.

Here, we considered two types of social status that a poster has. First, as a member of the organization, a poster will be assigned a formal organizational role (i.e., position) and gains certain power and social status. Generally, the vertical integration of positions forms a hierarchy within one explicit organization [48]. High position rank means that the organization and members identify an employee's ability and experience [80]. Research on organizations has evidenced that high position rank can help employees obtain favorable outcomes. In an electronic network within a high-tech company, Constant *et al.* [12] evidenced that users with a higher hierarchical position are more likely to provide useful advice. More recently, Riemer *et al.* [48] found that at an ESM site, messages from users with high position rank in organizations will receive a reply from group members faster. Accordingly, we posed the following hypothesis.

H4a: In a specific group, problem-solving by a poster with a higher position rank is more likely to be engaged.

Second, as a member of an online community, a poster can also earn social status by contributing content rather than being assigned [24]. Research has shown that online communities often exhibit participation inequalities and core-periphery structure through which the vast majority of content is contributed by a relatively small number of users [81]. A conceptual study by Levina and Arriaga [82] argued that status production and distinction in online communities can become a dynamic process through content contribution. Therefore, there are distinct classes of users that occupy varying levels of content creation and importance in online communities [25], [81]. The core or active users are the main contributors, while the periphery or passive users consume. Although both are important, we believe that user classes can play as dynamic labels that other users can use to perceive the poster's social status differently. According to social exchange theory, people tend to help those who helped them [83]. Additionally, a poster with higher user classes means a higher level of social presence in online communities, which promotes other users to form a positive impression
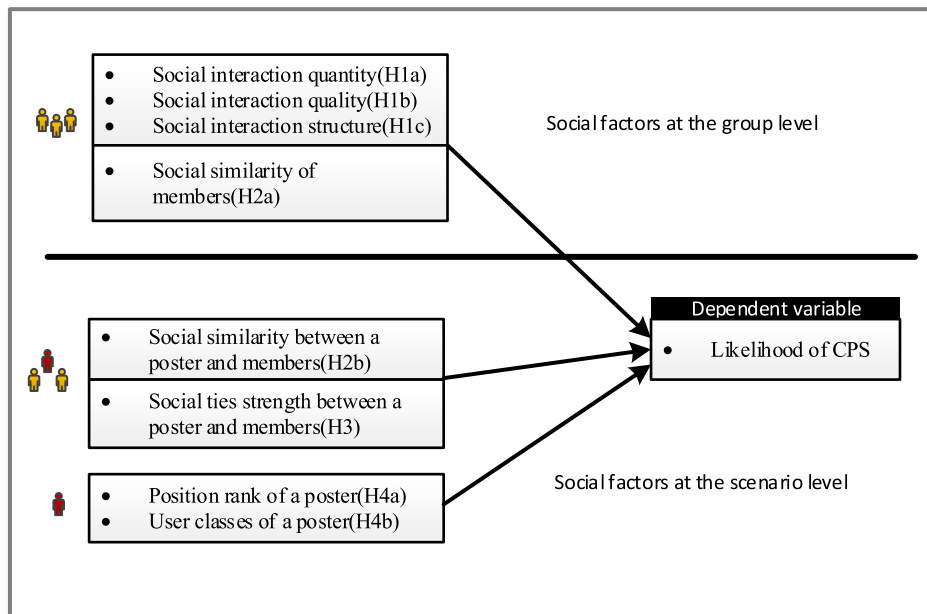
FIGURE 2. The emergence of CPS practices in ESM communities: A theoretical model.

toward the poster [84]. In turn, the positive impression ensures that other users are more willing to team and collaborate with the poster. Therefore, we hypothesize the following.

H4b: In a specific group, problem-solving by a poster with higher user classes is more likely to be engaged.

These hypotheses are summarized in Figure 2 and form the theoretical model of our study.

IV. RESEARCH METHOD

A. RESEARCH SETTING

The data for our study come from MUST, the internal ESM site of an online games firm. Established in 2004 and headquartered in Shanghai, the firm has released more than 20 online games, with several billion CNY in annual revenue. A senior vice president of the firm mentioned that "Before introducing MUST, many of our employees use public social media sites for communicating in the workplace". Using public social media in the workplace may engender privacy risk and waste time [85]. Against this background, in October 2013, the company introduced the tool to strengthen internal communication, collaboration, and knowledge sharing. Similar to other ESM software (such as Yammer and DingTalk), MUST can be privatized to a company's internal network [17].

MUST mimics in look, feel, and basic functionalities popular social networking sites such as WeChat [86]. It provides users with three primary channels for interactions: "Enterprise chat" for private dyadic communication, "Working circle" for posting work dynamics, and virtual groups. As one of the basic functional building blocks of social media, groups become subcommunities of people with common background, qualifications, or interests [87]. Recent studies on ESM have also showed that employees

share knowledge and collaborate through building virtual groups [41], [48], [88]–[90]. Similarly, MUST allows users to freely establish and join groups. However, as a marked difference from public social media sites, MUST groups add a problem-based module that allows members to release personalized problems. In this sense, when one member of a specific MUST group uses the function to release a problem, a problem-solving scenario arises. Therefore, our study focuses on problem-solving scenarios in MUST groups rather than other places. We would like to note that MUST groups are open to anyone in the organization, and the company only provided us with numeric identifiers of users, groups, and problems. Additionally, the content through "Enterprise chat" for private dyadic communication was excluded so that we just focused on the communication network rather than content.

MUST in the company represents the desired site for examining our research questions. On the one hand, the online game industry is a knowledge-intensive industry in which the phenomenon of CPS is salient. In particular, the firm mainly organizes its structure with teams in terms of different games and technologies (e.g., music). A team-oriented structure easily leads to information silos and is not conducive to CPS across teams [91]. Therefore, a high rate of seeking help through MUST is expected. On the other hand, MUST groups are designed to support CPS by adding a problem-based module. Consequently, the problem-solving scenarios that are generally implicit in similar software (e.g., enterprise microblogging) become explicit in MUST groups. In this sense, we can capture these CPS at the scenarios level, which enables researchers to directly and structurally code them rather than identifying them with a manual method that prior studies often used [24]. The manual content analysis only

TABLE 1. Summary of meta-information included in the MUST dataset.

Analysis unit	Meta-information
Groups	ID; builder and members; message thread (i.e., who posted what content at what time).
CPS scenarios	ID; text description of the problem; group; poster; comment thread (i.e., who comment at what time).
Users	ID; profile (e.g., position title and department title); work dynamic thread (i.e., who posted what content at what time); private communication network (i.e., who communicated with whom at what time).

offers a small sample and has reliability problems. Therefore, MUST groups can provide an ideal data environment for our study.

B. VARIABLE MEASUREMENT AND SAMPLE PREPARATION

The available data covered the period from March 21, 2014, to September 31, 2016. Table 1 presents a summary of the MUST dataset's meta-information that we can use to measure the variables in our study (see Table 3). As mentioned above, a problem-solving scenario arises in a MUST group when one member of the group posts a problem. Therefore, whether or not a problem-solving is engaged can be directly observed because the dataset recorded the information about comment thread (i.e., who comment at what time) of each problem-solving scenario. Therefore, CPS equals 1 when we observed at least one comment coming from other members in the group and 0 otherwise.

1) SOCIAL INTERACTIONS AT THE GROUP LEVEL

There are three variables related to social interactions. We measured the social interaction quantity by calculating the average number of messages across members of a specific MUST group. For the measurement of social interaction quality, we used the average number of bytes of messages across members [58], [59]. To measure the structure feature of social interactions, we utilized the standard deviation of messages number across members [60], [61].

2) SOCIAL SIMILARITY AT THE GROUP LEVEL

The dataset provided users' position title and department title. According to prior studies [12], [48] and the unique feature of the organization, we classified users' department into four types: top management, game operation, technological support, and general function. Likewise, users' positions are also divided into four ranks from high to low according to their hierarchical levels. This operation allows us to calculate two types of social similarity among members of a specific group. Formula (1) is used to computer group dissimilarity or diversity, a reverse measurement of similarity at the group level [68].

Here, P_i represents the proportion of the group that has each diversity characteristic. Therefore, we expect that the two variables, department-based diversity (DEP_DIV) and position-based diversity (POS_DIV), have negative coefficients.

$$\text{Dissimilarity} = \sum -P_i (ln P_i) \tag{1}$$

3) SOCIAL SIMILARITY AT THE SCENARIO LEVEL

The above classifications of users' department and position were also used to compute the degree to which a poster and potential collaborators are similar, which we assessed with a so-called affinity score, as computed by Formula (2) [24]. In the formula, relation$_i$ refers to the relation score between the poster i and members in a specific group with a size n. In particular, d_{ij} is used to define the dyadic relation between the poster i and a specific member j. Accordingly, the department-based social similarity between a poster and other members (DEP_SIM) can be computed by letting d_{ij} equal 1 when the poster i and the member j have the same type of department. Similarly, the position-based social similarity between a poster and other members (POS_SIM) can be computed by letting d_{ij} equal 1 when the poster i and the member j have the same type of position.

$$\text{Relation}_i = \frac{1}{n-1} \sum_{j=1}^{n} d_{ij} \tag{2}$$

4) SOCIAL RELATIONSHIPS AT THE SCENARIO LEVEL

To depict the social relationships between a poster with potential collaborators, the variable social ties strength (SOC_TIE) is also measured with Formula (2). As suggested by prior studies [70], [76], we used users' private communication networks in MUST to compute the social ties strength. Here, d_{ij} is equal to 0 when there is no actual dyadic communication between the poster i and member j and is otherwise 1.

5) SOCIAL STATUS OF POSTERS AT THE SCENARIO LEVEL

According to prior studies [12], [48], we used the above-defined four hierarchy levels to represent a poster's position rank (POS_RANK). For the measurement of user classes, we employed the cluster analysis procedure of a two-step method to distinguish different clusters by collecting data related to users in three channels that MUST provides (i.e., Enterprise chat, Working circle, and groups). This method has been used to identify user types in online communities [25], [81]. Users' work dynamics, group messages, and private messages were aggregated at the individual level separately. The outcomes of the cluster analysis are presented in Table 2. The quality of the cluster solution was 0.9, which is above the 0.5 threshold based on Schwarz's Bayesian information criterion (BIC) [25]. An examination

Cluster	One	Two	Three
Cluster label	Core users	Active users	Periphery users
Cluster size (N)	66	581	9448
Cluster size (%)	0.7	5.8	93.6
Input variables			
Work dynamics	794.14	71.81	1.50
Group messages	2053.42	652.04	13.74
Private messages	1207.52	90.77	3.97
Ratio	1:2.6:1.52	1:9.1:1.3	1:9.1:2.6

Note: To reduce bias, cluster analysis was conducted with all users enrolled in the MUST community rather than posters in the sample.

of Table 2 reveals not two but three distinct classes of users in the MUST community based on users' contribution amounts. Therefore, the variable user classes have three values: the core user class, the active user class, and the periphery user class. Consequently, three dummy variables were included: USE_CLA_COR, USE_CLA_ACT, and USE_CLA_PER.

6) CONTROL VARIABLES

In addition, we controlled many variables that have potential effects on the likelihood of CPS in MUST groups. First, the problem topic acted as a control variable because the features of a problem (e.g., complexity) can affect members' attitudes toward engagement with the problem [1]. Considering that these problems in MUST groups are unstructured, personalized, and unpredictable, we used the latent Dirichlet allocation (LDA) model [92], to determine the topic of the problem involved in each CPS scenario. LDA is a document-level probabilistic model and has been applied extensively in topic modeling.

Figure 3 presents the detailed procedures for how the LDA algorithm is used for problem topics classification. First, the text description of problems was preprocessed and then acted as the input variables of the LDA model. Then, the perplexity index was chosen to ensure an optimal number of topics, and 10 topics were returned with a suitable perplexity. In doing this, we can acquire a control variable "problem topic", which has 10 dummy values. In addition, we did not further explicate the 10 topics at the present stage because of the high complexity of these 10 problem sets. Fortunately, the classification information about these problems is enough for the economic analysis in this study. We would like to note that identifying and understanding the topics of these problems are important issues.

We also added a season variable for controlling the effects of time. For the association between user classes and the likelihood of CPS, we controlled a poster's activities related to problems. The total number of posted problems in all MUST groups (BTN), the number of posted problems in the specific group (BTGN), the total number of engaged problems in all MUST groups (DTN), and the number of engaged problems in the specific group (DTGN) are controlled. Additionally,
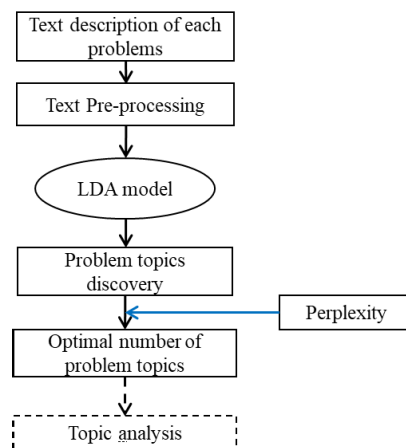

FIGURE 3. Flowchart of the LDA model for problem topic classification.

whether a poster is the builder of the specific group was controlled. Finally, features of MUST groups were controlled, including size, duration, and whether or not the group has a text-based description. After successfully measuring these variables, we could organize an available sample and build an economic model to analyze the relationships between these social factors and the emerging of CPS.

To match the data with our research questions, we organized our sample at the scenario level. Accordingly, a valid MUST group includes at least two members (including the builder) who posted at least one problem. Therefore, some MUST groups that only included one member or did not use the problem function were excluded. Finally, our sample included 10101 problem-solving scenarios embedded in 519 MUST groups.

V. DATA ANALYSIS AND RESULTS
A. MODEL IDENTIFICATION
The sample in our study has a nested structure, namely, problem-solving scenarios nested in groups. Such a multilevel structure violates the basic assumptions of single-level regression [93]. Additionally, our study explores the associations between high-level independent variables (i.e., social interactions and social similarity) and a low-level dependent variable (i.e., CPS). Single-level regression only generalizes

TABLE 3. Explanation of main variables.

Variable	Interpretation
CPS	Whether or not a poster's problem-solving is engaged by other members
MES_NUM	The average number of messages posted by the group's members
MES_QUA	The average byte number of messages posted by the group's members
MES_STR	The standard deviation of messages number across the group's members
DEP_DIV	The department diversity of the group's members
POS_DIV	The position diversity of the group's members
DEP_SIM	The department similarity between a poster and other members of the group
POS_SIM	The position similarity between a poster and other members of the group
SOC_TIE	The social ties strength between a poster and other members of the group in the private communication network
POS_RANK	The position rank of a poster
USE_CLA	The emerging status in terms of a poster's overall content contribution in the community

TABLE 4. Descriptions and correlations among main variables.

	Mean	S.D	CPS	DEP_SIM	POS_SIM	SOC_TIE	POS_RANK	USE_CLA
Variables at the scenario level (n = 10101)								
CPS	0.086	0.280	1.000					
DEP_SIM	0.600	0.375	-0.075	1.000				
POS_SIM	0.977	0.087	0.005	0.053	1.000			
SOC_TIE	0.636	0.313	-0.061	0.657	0.112	1.000		
POS_RANK	2.071	1.289	0.082	-0.322	-0.187	-0.484	1.000	
USE_CLA	1.333	0.646	-0.041	-0.402	-0.046	-0.586	0.409	1.000

	Mean	S.D	MES_NUM	MES_QUA	MES_STR	DEP_DIV	POS_DIV
Variables at the group level (n = 519)							
MES_NUM	14.275	43.488	1.000				
MES_QUA	897.874	3368.618	0.928	1.000			
MES_STR	38.564	105.259	0.751	0.660	1.000		
DEP_DIV	0.656	0.647	0.006	-0.039	-0.032	1.000	
POS_DIV	0.984	0.900	0.207	0.173	0.203	0.620	1.000

the value of a high-level variable in the same group; thus, it does not capture the nature of these high-level variables [94]. Therefore, the current study applied a multilevel modeling strategy to perform model identification. Multilevel modeling can partition the variance of a dependent variable into multiple levels and decompose the effects on different levels [24]. The assumption of observation independence for single-level regression is not required for multilevel modeling.

Additionally, CPS, the dependent variable in our study, is a binary type. Therefore, we used multilevel logistic modeling, which has been adopted in recent social science research [95]. According to the suggestion by Sommet and Morselli [96], we first built an empty model without including any covariates to assess the variation of the log-odds, namely, $\log\left(\frac{\text{prob}(CPS_{ij}=1)}{\text{prob}(CPS_{ij}=0)}\right)$ from one group to another:

$$\log\left(\frac{\text{prob}(CPS_{ij} = 1)}{\text{prob}(CPS_{ij} = 0)}\right) = \beta_{0j} \qquad (3)$$

and

$$\beta_{0j} = \gamma_{00} + \mu_{0j} \qquad (4)$$

Formula (3) is the within-scenario logistic model for the odds of CPS with unconditional covariates, and β_{0j} is the scenario-level intercept. Formula (4) is the between-group model for the odds of CPS with unconditional covariates,

γ_{00} is the overall intercept, and μ_{0j} is the group-level error term, which is assumed to be normally distributed with mean zero and variance τ^2. By identifying the empty model, we can acquire the estimator of τ^2. Because of the assumed standard logistic distribution at the scenario-level, meaning a variance component of $(\pi^2/3) \approx 3.29$, we can use the following Formula (5) to calculate the intraclass correlation coefficient (ICC):

$$\text{ICC} = \frac{\tau^2}{\tau^2 + (\pi^2 + 3)} \qquad (5)$$

The ICC quantifies the degree of homogeneity of the log-odds within groups [96]. The estimated value of τ^2 is 2.4 (standardized error = 0.557), so ICC = $\frac{2.4}{2.4+(\pi^2+3)} \approx 0.42$. This outcome indicates that 42% variance of the log-odds of CPS is explained by between-group differences, suggesting that a multilevel logistic model is necessary and reasonable.

Then, we built the final model by adding group-level predictors and scenario-level predictors:

$$\begin{aligned}
\log&\left(\frac{\text{prob}(CPS_{ij} = 1)}{\text{prob}\left(CPS_{ij} = 0\right)}\right) \\
&= \beta_{0j} + \beta_1 \cdot X_{DEP_{SIM\,ij}} \\
&\quad + \beta_2 \cdot X_{POS_{SIM\,ij}} + \beta_3 \cdot X_{POS_{RANK\,ij}} + \beta_4 \cdot X_{USE_{CLA_{COR\,ij}}} \\
&\quad + \beta_5 \cdot X_{USE_{CLA_{ACT\,ij}}} + \beta_6 \cdot X_{SOC_{TIE\,ij}} + \beta_7 \cdot X^2_{SOC_{TIE\,ij}} \\
&\quad + \beta_{contrl} \cdot X_{contrl_{ij}} \qquad (6)
\end{aligned}$$

TABLE 5. Multilevel logistic regression of social factors on CPS.

	Odds	Odds ratio
Intercept	0.002***	-6.149***
	(0.002)	(1.009)
Main variables at the group level		
MSG_NUM	1.001	0.001
	(0.005)	(0.005)
Log(MSG_QUA)	1.184*	0.169*
	(0.077)	(0.065)
MSG_STR	0.994*	-0.006*
	(0.002)	(0.026)
DEP_DIV	0.959	-0.041
	(0.342)	(0.357)
POS_DIV	0.680	-0.385
	(0159)	(0.234)
Main variables at the scenario level		
DEP_SIM	0.814	-0.205
	(0.256)	(0.315)
POS_SIM	7.278*	1.985*
	(5.782)	(0.794)
SOC_TIE	0.071***	-2.652***
	(0.055)	(0.779)
SOC_TIE×SOC_TIE	6.213**	1.827**
	(3.945)	(0.634)
POS_RANK	1.010	0.009
	(0.131)	(0.129)
USE_CLA_COR	4.799***	1.568***
	(1.314)	(0.274)
USE_CLA_ACT	2.368*	0.862*
	(0.648)	(0.274)

Log-likelihood: -2605.998, AIC: 5285.998, and BIC: 5553.152

Notes: Odds equals to exp (Odds ratio); we take a log of MSG_QUA because its value is large (see Table 4); for the variable user classes, the category of periphery users as a baseline was omitted; parentheses are the standard error of the coefficient; *p < 0.05, **p <0.01, and ***p <0.001.

and

$$\beta_{0j} = \gamma_{00} + \gamma_1 \cdot X_{MSG_{NUM_j}} + \gamma_2 \cdot \log\left(X_{MSG_{QUA_j}}\right)$$
$$+ \gamma_3 \cdot X_{MSG_{STR_j}} + \gamma_4 \cdot X_{DEP_{DIV_j}} + \gamma_5 \cdot X_{POS_{DIV_j}}$$
$$+ \boldsymbol{\gamma}_{control} \cdot \boldsymbol{X}_{control_j} + \mu_{0j} \qquad (7)$$

Formula (6) is the within-scenario logistic model for the odds of CPS with conditional covariates, the term $\boldsymbol{\beta}_{contrl} \cdot \boldsymbol{X}_{contrl_{ij}}$ refers to control variables at the scenario-level, and β_{0j} is the scenario-level intercept. Formula (7) is the between-group model for the odds of CPS with conditional covariates, the term $\boldsymbol{\gamma}_{control} \cdot \boldsymbol{X}_{control_j}$ refers to control variables at the group-level, γ_{00} is the overall intercept, and μ_{0j} is the group-level error term.

B. HYPOTHESIS TESTING

We tested our hypotheses by identifying the final model. The results of the multilevel logistic model for CPS are presented in Table 5. The outcome of a chi-square test showed that this model has a significant improvement relative to the standard logistic model (c = 134, p < 0.001) [97]. Although Table 5 reported the coefficients in terms of odds and odds ratio, we test our hypotheses based on the odds ratio.

At the group level, Table 5 showed that although the variable MSG_NUM has a nonsignificant coefficient, the variables MSG_QUA and MSG_STR are positively and negatively related to the likelihood of CPS, respectively.

Thus, H1a is not supported, but H1b and H1c are supported. For social similarity at the group level, the effects of the variables DEP_DIV and POS_DIV are not significant, not supporting H2a. Furthermore, the results showed that social similarity at the scenario level has inconsistent relationships with the likelihood of CPS. That is, the variable POS_SIM has a significant and positive coefficient, whereas the variable DEP_SIM is not significant, thus partially supporting H2b.

In terms of other social factors at the scenario level, Table 5 first indicated the U-shaped association between the variable SOC_TIE and the odds ratio of CPS. Specifically, the variable SOC_TIE has a significant and negative coefficient, but its square has a significant and positive coefficient, thus supporting H3. Based on the current dataset, Figure 4 presents the simulated outcome of the effects.

Finally, the results showed that the variable POS_RANK is unrelated to the odds ratio of CPS, not supporting H4a; however, the variables USE_CLA_COR and USE_CLA_ACT have positive effects on the likelihood of CPS, thus supporting H4b. Table 6 summarizes the hypothesis testing results.

VI. DISCUSSIONS

A. KEY FINDINGS

First, we found that features of social interactions at the group level have different relationships with the likelihood of CPS in ESM groups. Specifically, the average number of messages does not engender effects; for a 1% increase in the
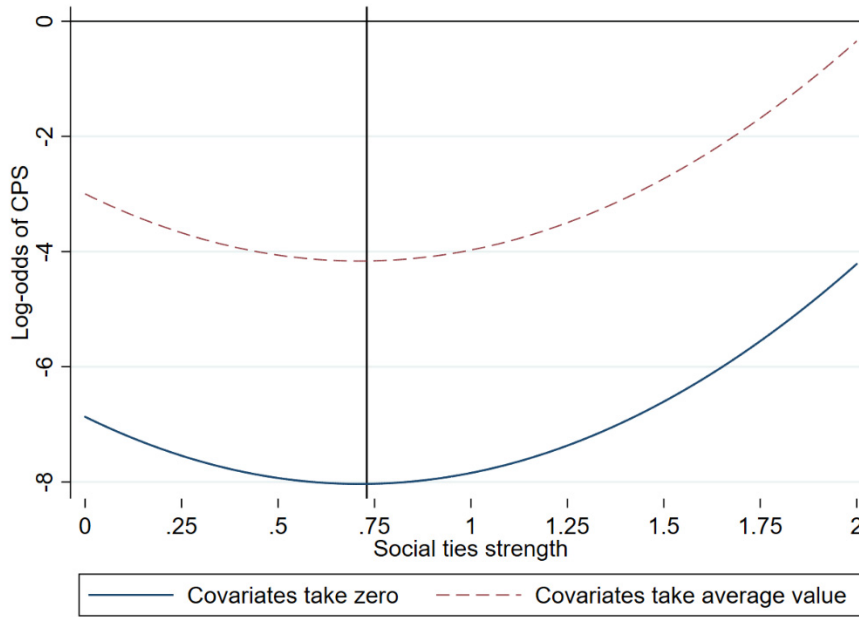
FIGURE 4. Stimulation of the relationship between social ties' strength and log-odds of CPS.

TABLE 6. The results of hypotheses testing.

Hypothesis	Decision
H1a: Problem-solving is more likely to be engaged in groups with a greater number of social interactions	Not supported
H1b: Problem-solving is more likely to be engaged in groups with a higher quality of social interactions	Supported
H1c: Problem-solving is less likely to be engaged in groups with a higher centralization degree of social interactions	Supported
H2a: Problem-solving is more likely to be engaged in groups whose members have a higher social similarity	Not supported
H2b: In a specific group, problem-solving by a poster who has a higher social similarity with other members of the group is more likely to be engaged	Partly supported
H3: In a specific group, the social ties strength between a poster and other members of the group has a U-shaped association with the likelihood that the poster's problem-solving is engaged	Supported
H4a: In a specific group, problem-solving is more likely to be engaged by a poster with higher position rank	Not supported
H4b: In a specific group, problem-solving is more likely to be engaged by a poster with higher user classes	Supported

number of the average bytes of messages, the odds ratio of CPS increases by 0.169; the standard deviation of messages number across members decrease by one unit, the odds ratio of CPS increases by 0.006. These outcomes indicated that for increasing the probability of CPS in ESM groups, it is important to improve the message quality and keep the equalization of social interactions among members. Immoderate messages in ESM groups should not be encouraged. Researchers have argued that CMC communication tends to lead to impersonal interactions because of the absence of nonverbal cues, such that members find it more difficult to perceive implicit meanings from CMC messages and build mutual understanding and trust [98]–[100]. Research has also indicated that in CMC-mediated groups, members mainly pay their attention to work-related information, such that a mass of messages may increase the cost of identifying useful information and decrease the motivations to collaborate [56], [101]. In terms of social interaction structure, decentralized communication

in CMC-mediated groups increases the overall identification and improves the efficiency of collaboration.

Second, the results also suggested that the social similarity between a poster and other members in ESM groups is beneficial to the likelihood of CPS. Specifically, when position-based similarity increases by one unit, the log-odds of CPS increases by 1.985. Similar positions mean that employees have similar work practices and cognitive proximity. Therefore, such similarity enables that members have the necessary knowledge and ideas to collaborate with the poster [9], [66], [67]. A recent study by Di Tommaso *et al.* [102] also found that employees with the same position rank are more likely to build groups and interact with each other. Our findings provide evidence to support the assertion that users are more likely to interact with similar people in ESM communities.

Third, we identified a U-shaped relationship between social ties strength and the likelihood of CPS. In other words,

the likelihood of CPS is greater when the social ties strength between a poster and other members in ESM groups is low or high than when the social ties strength is medium. Research on ESM has shown that employees use the tool to socialize and develop and maintain their social network within organizations [85], [103], and they can benefit from the social network [104], [105]. Our finding may imply the process that social ties strength influences collaboration is more complex. The advantage of weak ties in increasing the likelihood of CPS will fade away as the strength increases, but the advantage of strong ties gradually emerges and increases as the strength increases.

Finally, two types of social status of posters have different effects on the likelihood of CPS. Specifically, the findings suggest that an emerging social status based on users' contributions (i.e., user classes) can increase the likelihood of CPS, but a formal social status (i.e., position rank) does not. We note that recent research on ESM has emphasized the social nature of ESM [106]. Investigations toward individuals also found that users contribute content to ESM sites mainly because of intrinsic motivations and social needs [107], [108]. In this sense, members may be more likely to collaborate with users who are more active in ESM communities rather than users who have a high hierarchy rank in their formal organization [48]. The study by Riemer *et al.* [48] indicated that in ESM groups, the effects of the hierarchy level gradually weaken, but the influence of contributions gradually increases. The finding is also consistent with prior research on public online communities [81].

B. THEORETICAL IMPLICATIONS

The theoretical implications of the study are twofold. First, the study contributes to the existing ESM literature significantly by exploring the relationships between many social factors and the emerging of practices in ESM groups from a multilevel perspective. Specifically, the study further indicated that social factors at the level of both groups and scenarios can affect the occurrence of CPS in ESM communities. At the group level, we found that quality and centralized degrees of social interaction can promote the happen of CPS. At the problem-solving scenario level, the study found that social relationship with other members is important. Interestingly, the results also evidenced that users' contributions in the community rather than their hierarchy in the organization can increase the likelihood of CPS.

Although previous researchers pointed out its nature of the community of practice, extant empirical studies focused on individuals' reported behavior rather than actual practices in ESM sites [27], [28]. No studies considered actual and work-related practices and their enablers in ESM communities. In this sense, our study can bridge the theoretical gap that we still have little understanding of how actual practices occur in ESM sites. Drawing on different social theories, our study developed and tested a theoretical model of how social forces are related to the emerging of CPS in ESM groups.

Second, the study also provides implications for the literature on CPS in organizational research. Prior studies in this stream mainly focused on CPS in the formal workgroups or teams [2], [10]. Organization scientists have advanced the perspective of the community of practices [5]. According to the perspective, CPS practices may appear in the form of self-organization. In this sense, our study provides evidence that social forces can play crucial roles in promoting the emerging of CPS in organizations. Furthermore, our study recommends that scholars in an organization consider the actual work practices rather than abstract behavior, and probe the structure of these practices. For example, our research showed that collaborative practices may have a multilevel structure.

C. PRACTICAL IMPLICATIONS

As increasingly more companies introduce ESM sites within their organizations, it is expected that employees will spend considerable time participating in such sites. Our study focuses on the CPS practices in ESM groups, one of the most often and important practices for companies, and can provide several practical implications.

First, we found that social interaction quality and structure can increase the likelihood of CPS. In this line, ESM group members need to know that the improvement of the message quality and making the distribution of messages among members more even is crucial for increasing efficiency. We do not encourage immoderate postings in ESM groups.

Second, as a member, users' social similarity with other members of the ESM group is important. When having a choice of ESM groups, users should join groups that have members with similar position rank.

Third, users' social ties strength has a U-shaped relationship with the likelihood of CPS. This means that users need to manage their social networks in ESM sites and strategically choose the groups when they want to solve problems. A group full of strangers may offer a low likelihood of acquiring help. Furthermore, users should continue to enhance their relationship with other members if they already have a strong relationship with themselves. However, users should not strengthen the relationship with other groups if they already have a weak relationship with themselves.

Finally, users can earn social influence from their prior contributions in ESM communities and raise the likelihood of CPS. Therefore, users should actively participate in ESM communities, which in turn can help them to accumulate social status and acquire help. We note that a high position rank does not mean a quick response and a high rate of help from other users.

D. LIMITATIONS

Inevitably, the study has several limitations. First, our study used a cross-sectional design and measured the variables with a relatively rough caliber. Second, although we explored many social factors according to the meta-information that a unique dataset provided, it is possible that some important social factors are omitted because of limited information.

Finally, the data in our study come from a company in China. Cultural variation may decrease the generalization of our findings. These limitations could suggest further research directions.

VII. CONCLUSION

Enterprise social media tools are popular within companies distributed in different industries. Such tools provide new space for employees to coordinate to solve work-related in daily routines. However, managers often concern about the social nature of such tools and lack the knowledge of how they can improve employees' efficiency in collaboration with such tools. By drawing on different social theories and analyzing a unique dataset including 10101 problem-solving scenarios embedded in 519 ESM groups, this research may offer some contributions. Our study found that frequency, as well as decentralized degree, of social interactions among members of the ESM group, are beneficial to collaboration for problem-solving. Furthermore, if a poster is more similar to other members of the group in position, his/her questions become more likely to be responsive. Additionally, higher user classes status of posters that can be acquired by actively participating the ESM communities increase the likelihood of CPS. Finally, social ties' strength between a poster and members in a specific ESM group has a U-shaped effect on the likelihood of CPS.
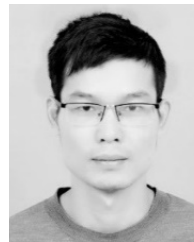
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