A deeper investigation of different types of core users and their contributions for sustainable innovation in a company-hosted online co-creation community

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Abstract: Online co-creation allows pooling external sources of knowledge to maintain sustainable innovation process. Users' knowledge is regarded as one such potential source. Understanding user behaviors and innovation types is vital to integrate resource improving social sustainability of a community or even larger society. Many prior studies mainly categorized online community members into core and peripheral members based on their posting behavior. However, little research has gone beyond that categorization and examined whether there may be different types of active community members who contribute to social concerns differently, especially in the context of co-creation. The objectives of this study are threefold: (1) to identify the core members of a company-hosted online co-creation community automatically by considering several dimensions of individual members, including posting behavior, the generated content, and social network features; (2) to categorize and compare the contributions of different types of active users in that community, aiming to identify community members who may play leadership roles in sustainable innovation; and (3) to investigate the influence of those different types of active users on other community members. The data collected from a company-hosted online co-creation community in China were analyzed. Through analysis, we developed a novel innovation-oriented topology of active community members that consists of eight types. Based on Practice Theory, we also explored how those different types of active community members may influence other members' behavior. Finally, based on the findings, we propose strategies and guidelines for practitioners to keep different types of community members actively engaged in online co-creation and to manage sustainable innovation practice.

Keywords: company-hosted online community; member; sustainable innovation; co-creation

1. Introduction

The concept of sustainable innovation (SI) has attracted the interest of academics and practitioners due to increased concern for global sustainability over the last decades (Caiado, de Freitas Dias, Mattos, Quelhas, & Leal Filho, 2017; Rosca, Arnold, & Bendul, 2017). The term SI refers to an advance in products or services improving economic performance with less externalities in the form of social hazards (Nielsen, Reisch, & Thøgersen , 2016). Overcoming SI entails the involvement of a wide range of people possessing different interests and covering broad capabilities (Kruger, Caiado, França, & Quelhas, 2018 ; Liedtke, Baedeker, Hasselkuß, Rohn, & Grinewitschus, 2015). Therefore, external sources of knowledge are the key to the SI process in which users are regarded as one such powerful source(Nielsen et al., 2016). Co-creation is an iterative process as it allows bringing different parties together to jointly produce a mutually valued outcome (Kruger et al., 2018). As such, the co-creation practice can act as a strategy for pooling external knowledge and constructing pathways to sustainable futures (Camacho-Otero, Boks, & Pettersen, 2019; Nielsen et al., 2016).

Particularly promising digital approaches provide a range of communication channels to engage knowledgeable but physically separate users(Fuger, Schimpf, Füller, & Hutter, 2017; Hyysalo, Johnson, & Juntunen, 2017). An increasing number of companies in different industries have created and maintained Company-hosted Online Co-creation Communities (COCC) to meet social criteria in which individuals and companies that share common interests, a sense of belonging, and rules for participation and governance would communicate and collaborate to put companies in a favorable, competitive position through online interactions and information sharing among stakeholders and between stakeholders and companies (Jeppesen & Frederiksen, 2006; Piller, Ihl, & Vossen, 2010; Rullani & Haefliger, 2013). Sustainable product/service co-innovation is often an essential component of COCC. Although users integrate personal experience to innovate, they also benefit other stakeholders to improve social or health condition of a community or even larger society (Nielsen et al., 2016). For example, companies in China increasingly involve in online consumer communities to

facilitate sustainable user innovation. According to China Internet Watch[1], a variety of online communities have been created and managed by companies and entrepreneurs in China, such as WeChat Group by Tencent and Huafen by Huawei. Those communities provide a variety of tools in support of communication among community members.

User participation is vital to the sustainability and timeliness of online co-creation (Kruger et al., 2018). Practice theory also suggests that core members of a community set the standards of excellence (quality, communication) through their non-material artifacts as a social practice, as a result influencing the social condition and behavior of other community members(Rullani & Haefliger, 2013). Here core members are referred to as active members who frequently post in a community (Chen, Cheng, and Liu 2008).To motivate user engagement and live up to social criteria, for both practitioner and researchers, a clear understanding of user behaviors and their contributions to COCC is needed (Hyysalo et al., 2017; Jaakkola & Alexander, 2014; Nielsen et al., 2016). In an online community, well-defined user roles would better facilitate communication, learning, knowledge exchange and the sustainability of an online community (Brown, 2001; Herrmann, Jahnke, & Loser, 2004). There has been some prior research on the roles and motivations of community members. For example, Füller, Hutter, Hautz, and Matzler (2014) identified six member types in an innovation contest community, showing both cooperation and competition among community members. Johnson, Safadi, and Faraj (2015) found that community leaders made many positive and concise posts with simple language familiar to other members. Lim and Kumar (2017) identified information, entertainment, and connectedness as motives for predicting one's commitment to a community. Benamar, Balague, and Ghassany (2017) proposed that core members contribute to the creation and diffusion of cookery as a social practice, in turn shaping the behavior of other members.

[1] https://www.chinainternetwatch.com/18994/online-community-2016/

However, there are several limitations and gaps of the literature. First, Many prior studies differentiated core members of a community from peripheral members largely based on their posting frequency (Edelman, 2007; Hojman & Szeid, 2008; X. Zhang, Martin, & Newman, 2015). The full potential of co-creation within sustainability remains less explored (Nielsen et al., 2016). Few studies in the literature have examined whether there are different types of core members in terms of what they contribute to social or health condition of a community, especially in a COCC context as user roles may vary depending on the purpose a community. Second, previous studies concerning motivations of participating in an online community mainly investigated factors that may affect user participation (Fernandes & Remelhe, 2016; Hossain, 2012). There is a lack of evidence and understanding of potential differences in the contributions of core community members with different motivations to social sustainability (Hyysalo et al., 2017; Nielsen et al., 2016). Third, it remains unclear how different types of core users may impact other members' behavior in a COCC (Rullani & Haefliger, 2013).

To fill those research gaps, this research intends to answer the following research questions:

RQ1: What types of behaviors of core members can be found in a COCC?

RQ2: How do different types of core members of a COCC contribute to SI differently?

RQ3: Do different types of core members of a COCC influence other members' engagement differently?

We deployed a three-phase methodological approach to address those research questions. First, we performed a two-step cluster analysis to cluster members of a COCC in China automatically based on features of multiple behavior dimensions of individual members, including posting activities, the posted content, and social network status. A portion of members were then identified as the most active members. Second, based on Uses and Gratification Theory (UGT) (Dolan, Conduit, Fahy, & Goodman, 2016), we developed a novel typology to further categorize core users based on three key aspects, including contribution type (e.g., innovative ideas, report of product problems, and solutions), target of interest (e.g., product, community, or personal life),

and individual orientation (e.g., socialization, venting emotions). Third, guided by Practice Theory (Rullani & Haefliger, 2013), we explored how different types of core members may influence co-creation behavior of other community members. Through the Kruskal-Wallis non-parametric test and pairwise comparisons, we validated that different types of core members have different impacts on other members, which were reflected by the generated comments from the latter.

This research makes three important research contributions: 1) to our best knowledge, this research is the first effort to elaborate behavioral differences of active members of a COCC in China; 2) by using UGT, we discovered which types of core members contributed to improve social sustainability in a COCC, which may be driven by different informational or social motivations; and 3) this research extends the prior work of Rullani and Haefliger (2013) and Benamar et al. (2017) by investigating internal dynamics, showing that different types of core members have different impacts on the behavior of other community members in the community. The findings of this research also provide practical insights on how to improve user engagement and promote SI practice.

The rest of the paper will be organized as follows. First, we will review the related work on taxonomies of online community members. Next, we will present the research methodology, followed by results of data analytics and discussions of research contributions and practical implications. Finally, the paper will be concluded with the discussion on the limitations of this study and future research directions.

2. Literature review

2.1 Online company-hosted co-creation community as a tool for SI

The term SI refers partly to an advance in products or services improving economic performance with less externalities in the form of social hazards (Nielsen et al., 2016). It entails combining resources, knowledge and capabilities from various stakeholders (Boons & Lüdeke -Freund, 2013). External sources of knowledge are the key to construct sustainable future (Nielsen et al., 2016). The more knowledgeable

stakeholders are involved, the more conducive to SI process (Kruger et al., 2018). Users who are eager to share innovative ideas or suggestions are regarded as one such powerful source(Nielsen et al., 2016). Co-creation is an iterative process, supported by sustainable knowledge learning, knowledge sharing and relationship management to realize product and service improvements (Arnold, 2017; Gluch, Johansson, & Räsänen, 2013). As such, the co-creation practice can play a key role in pooling external knowledge from users.

Particularly promising new digital approaches provide a range of communication channels to engage knowledgeable but physically separated users (Fuger et al., 2017). Various forms of online co-creation communities are supportive of sharing with community members, creating innovations together and adoption from community members (Hyysalo et al., 2017). To manage co-creation process more effectively, online user roles have been investigated in different backgrounds including innovation contest community (Füller et al., 2014 ; Guo, Zheng, An, & Peng, 2017; Moritz, Redlich, & Wulfsberg, 2018), crowdsourcing community (Fuger et al., 2017), open source software community (Barcomb, Kaufmann, Riehle, Stol, & Fitzgerald, 2018; Crowston & Shamshurin, 2017).

These user roles, in essence, innovate for themselves or producers based on their personal experience in product and service (Nielsen et al., 2016). The full potential of co-creation within sustainability remains less explored (Nielsen et al., 2016). In current time, the application of COCC possesses great significance for company to meet social criteria when pursuing a triple bottom line of sustainability (Lee & Dolen, 2015; Yang & Li, 2016). In a COCC, both customer-to-customer problem solving and customer-to-manager interactions are encouraged in a company-hosted website and the task assigned to customers is given in many degrees of freedom during new idea generation process (Piller et al., 2010). Co-creation sustainability concerning social aspect is the health condition of a community or larger society. For users who contribute to SI, their focus is no longer personal wants, but the needs of stakeholders including social concerns(Nielsen et al., 2016). Therefore, when innovating on the basis of personal

skills, users in COCC not only need to seek an advance in products and services for economic performance but also to meet social criteria as well (Nielsen et al., 2016). A better understanding of user growing role in SI would create a more conducive context for the specific type of innovation.

User roles may vary depending on the purpose and context of the community (Fuger et al., 2017). Therefore, the existing user types are no longer applicable to the COCC context. Our research seeks to advance the understanding of user roles in a specific COCC context.

2.2 Taxonomies of online community members

According to Welser, Gleave, Fisher, and Smith (2007), user types or roles in online settings can be defined based on quantitative, qualitative, and structural attributes of users. As such, researchers have deployed three general methods for identifying member types in online communities, including quantitative, qualitative, and structural approaches:

1) Qualitative approaches analyze context and content of communication generated by members of a community (Pfeil, Svangstu, Ang, & Zaphiris, 2011). This interpretative method allows the identification and understanding of member behaviors and the meaning behind their interactions (Füller et al., 2014).
2) Structural approaches employ social network analysis to categorize member roles in an online community based on metrics of structural relationships drawn from data on user interactions (Gleave, Welser, Lento, & Smith, 2009). This approach provides a view of community structure (Burt, 2005).
3) Quantitative approaches focus on examining the intensity of individual members' activities in an online community, such as the number of posts created and the number of stories shared in the community.

It has been suggested that only using a single approach for discovering the types of online community members is not sufficient. Instead, an integrative approach that combines two or more approaches would be more appropriate, especially when the goal

is to achieve a comprehensive understanding of fragmented, inconclusive, and equivocal phenomena like online communities (Venkatesh, Brown, & Sullivan, 2016). Some researchers have explored an integrated approach for different types of online communities (Fuger et al., 2017; Füller et al., 2014 ; Kou, Gray, Toombs, & Adams, 2018; Welser et al., 2007). For example, Pfeil et al. (2011) investigated online support communities and summarized characteristics of member behavior through content analysis and structural equivalence. Kou et al. (2018) studied an online user experience community. By applying linguistic analysis of user posts and comments and social structures, they identified 6 member types (i.e., knowledge broker, translator, experienced practitioner, conversation facilitator, and learner). Bo, Zhou, Jin, Lin, and Leung (2017) adopted a data mining approach to building a three-layer model for user segmentation.

Prior studies differentiated core member of a community from peripheral members largely based on their posting frequency. However, core members have their own preferred topics and as a result their posts are exposed to different audience (Benamar et al., 2017). Therefore, core members can contribute differently to the community. There has been little research on identifying different types of core users in a COCC and their contributions to SI.

2.3 The drivers to user participation

Several studies have investigated motivations of users to participate in an online community based on UGT. Uses and Gratifications Theory (UGT) posits that there are four types of benefits that individuals can derive from media usage (Katz et al., 1974), including cognitive benefits that relate to information acquisition and improvement of understanding of the environment; social integrative benefits that relate to strengthening one's ties with relevant others; personal integrative benefits that relate to strengthening the credibility, status, and confidence of an individual; and hedonic or affective benefits that enhance aesthetic or pleasurable experiences. For example, Whiting and Williams (2013) identified ten motives of individuals' use of an online

community, including contentedness, information seeking, pastime, entertainment, relaxation, expression of opinions, communication utility, convenience utility, information sharing, and knowledge about others. Researchers also proposed three key dimensions related to consumer use of online communities, including process (entertainment), socialization, and content (information need) (Chen, Yang, & Tang, 2013; F. Stafford, Royne, & L. Schkade, 2004; Peters, H. Amato, & R. Hollenbeck, 2007). Lim and Kumar (2017) identified information, incentives, entertainment, and connectedness as motives for predicting one's commitment to a community, which, in turn, strengthens brand attachment.

Existing research on member types of online communities, in essence, has been largely hinged on what motivate members to participate. Nielsen et al. (2016) hint to the importance of understanding the participants' behaviors and innovation types in SI process. We follow the research suggestion of Hyysalo et al. (2017) regarding the search for range of roles that users play in SI process as well as in the overall dynamics within the community. We determine categorize community core members and investigated whether different types of core members make different types of contributions to COCC, especially from a SI perspective.

2.4 Influence of core members on other community members

Practice Theory is a theory of how social beings, with their diverse motives and intentions, make and transform the world in which they live. It is a dialectic between social structure and human agency working back and forth in a dynamic relationship (Corsini, Laurenti, Meinherz, Appio, & Mora, 2019). Researchers have explored how a community regulation that contains social rules and shared values is diffused and guides the peripheral to participate in the community (Corsini et al., 2019). When peripheral members read the posts and comments generated by core members, they can be influenced by 'the footprint of the practice' contained in the content(Rullani & Haefliger, 2013).This may bring about the adoption and socialization of practice standards and in turn promote common ways of innovation (Benamar et al., 2017).

Understanding how the configuration of community leaders and their social interactions within community influence the performance of other community members is often discussed as needed future research in existing literature (Benamar et al., 2017; Xiao, Travis, & Newman, 2014). Especially, in the field of COCC there is a lack of evidence in literature about different types of core members' influence on other members (Benamar et al., 2017) and understanding which types of core members possesses greater influence in a community is of rising interest. As the investigated COCC allows users to either submit their ideas or make complains, we are able to examine which types of core members are most prominent and most valuable in communities.

3. Methodology

This study analyzed data collected from an online co-creation community, Huafen, hosted by Huawei Technologies, Co., Ltd. In China. Figure 1 shows the overall procedure of the study. First, through a two-step cluster analysis of individual members' activities including the generation of posts, comments, and likes, we identified core members. Second, via analysis of posts and comments generated by the core members, we examined how different types of core members contributed to the community and SI. Finally, based on Practice Theory (Rullani & Haefliger, 2013), we investigated potential influence of core members on other community members' contribution to SI from two perspectives, including social network structure and activity.

3.1 Data collection

We collected data from the Huafen online community (https://club.huawei.com/) in this study. Huafen is the official co-creation community created and hosted by Huawei Technologies, Co., Ltd for improving social sustainability. Huawei is a Chinese telecommunications equipment and consumer electronics manufacturer that produces a wide range of products including smartphones, tablets, wearables, PCs, and broadband and home devices. It was ranked 72_{th} among the Fortune 500 companies in 2018.Huafen

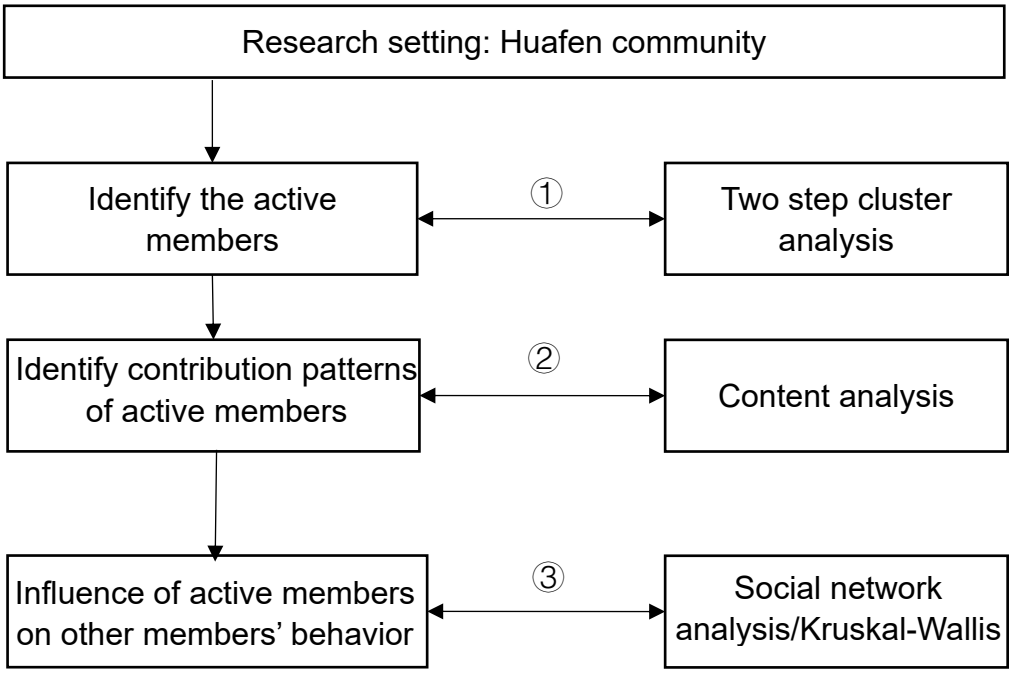

Figure 1. Research design

is aimed to distribute up-to-date information about Huawei products, provide solutions to consumers, and enable consumers to exchange and share their Huawei product experience through interactive activities in the community. Huafen is also a platform for Huawei to listen to consumers' voices for improving their products and achieving growth of consumers and company simultaneously. At present, Huafen has more than 20 million registered users.

There are many product series centered sub-communities in the Huafen community. We selected the sub-community associated with Huawei Mate20 smartphone series, which is the most active sub-community (i.e., with the largest number of members) in Huafen. We collected data from this sub-community generated between February 3rd and March 3rd, 2019. The data included 20,256 original posts generated by 13,248 non-manager community members, as well as 4,124 likes and 256,910 comments (i.e., responses). It is worth noting that the total number of posts and comments collected from that one-month period was close to 280,000, which is sufficient for data analytics. In order to control the scope and complexity of this study, we did not collect more data. Some previous studies on roles or types of online

community users also used similar short-term data or data with similar size (Akar, Mardikyan, & Dalgic, 2019; Bulgurcu, Osch, & Kane, 2018). However, the proposed methodology should be generic and applicable to larger data size. As many previous studies, we assume that the behavior of community members should be relatively consistent over time.

3.2 A three-phase procedure

To answer the research questions, we performed a three-phase analysis to discover core members of the Mate20 sub-community of Huafen in the time period. First, we analyzed individual members' activities including generation of posts, comments, and likes to identify core members. Then, via analysis of those members' post and comment content, we explored which product related issues different types of core members discussed to contribute to the co-creation process. Finally, through structural analysis, we investigated social positions of individual core members in the community according to their interactions with other community members.

Identification of core members through clustering

In the first phase, we aimed to identify core community members according to their activities in the community, which were assessed in three dimensions, including posts, comments, and likes, that would reflect members' active participation levels (Teichmann, Stokburger-Sauer, Plank, and Strobl (2015)). Specifically, we performed a two-step cluster analysis that combined both hierarchical and non-hierarchical methods (Moritz et al., 2018). We first used a hierarchical clustering algorithm using the Ward's minimum variance method to determine the number of clusters (k=4) for non-hierarchical clustering (Milligan & Cooper, 1987), then used the k-means algorithm to cluster those community members into four clusters based on seven

variables selected from literature (e.g., Benamar et al. 2017) and domain heuristics. Those seven variables included the number of original posts (i.e., a member's initiatives), the number of comments made, the number of received likes and comments (i.e., a member's influence on others), the average number of received comments per post (i.e., influence density), the average number of comments made per post (i.e., reaction density), the number of self-comments (i.e., the number of comments made on their own posts, indicating the degree of one's self-orientation), and the number of comments for community managers(i.e., user engagement in community activities held by company). At the end, we labelled the four generated clusters, with one of them being the core member cluster that consisted of 81 members who contributed 1,148 original posts and 13,362 comments during the data collection period. The detailed results will be reported in the results Section.

Analysis of post and comment content

After identifying core community members, we conducted a content analysis of 81 core members' posts and comments based on UGT to further categorize them in order to achieve a better understanding of their contributions to co-innovation at a finer granularity.

To understand the content generated by the core members of the community, the posts and comments of individual core members were coded around two questions: 1) what was the objective of a particular post or comment? We primarily focused on cognitive benefit (i.e., information acquisition) and social integrative benefit (i.e., satisfying the social need) of UGT; and 2) what was the main issue or topic discussed in the content (e.g., innovative idea about a product or experience with using a product). Finally, we developed 12 coding themes (i.e., categories) and associated motivation labels (Table 2). Two independent coders coded the posts/comments individually and then converged. The Cohen's Kappa coefficient was 0.76, indicating a strong agreement between the two coders (Landis & Koch, 1977).

Based on the prior work of Pfeil et al. (2011) and Benamar et al. (2017), we examined the difference ratio (in percentages) between a member's post and comment distribution across theme categories and the average distribution among all members for each category (Equation 1).

$$\text{Difference ratio} = \frac{N_{m_{ij}} - Mean_j}{Mean_j} \quad (1)$$

Where Nm_{ij} represents the number of posts and comments made by the i_{th} member in the j_{th} theme category, while $Mean_j$ represents the average number of posts and comments made by all of the core members in the j_{th} category. By doing this, we were able to identify which theme categories each active member contributed more (or less) than the average of core members based on difference ratio values.

Influence of core members on other community members

In this phase, we aimed to investigate potential influence of core members on other community members' contribution to co-creation. By following the Practice Theory, we examined how different types of core members influence other community members from perspectives of social network structure and level of activities. First, we used Gephi, an open-source social network analysis and visualization software package, to

Table 2. The final coding schemes used for content analysis

Contribution types	*Examples*
1- Product Innovation	
1.1 Innovative, new ideas related to new product design and product improvement	"It is recommended to add a password when turning of the phone."
1.2 Reporting product problems	"Mate20X mobile phone, bluetooth and Wifi conflict!"; "My phone consumes electricity significantly. How about yours?"
1.3 Product usage advice and suggestions	"Discover a new power saving setting!"
1.4 Discuss or share other companies' competing products	"Qualcomm and Huawei 5G baseband comparison."
1.5 Personal feelings about good or bad aspects of a product	"Mate20 Pro is my most satisfactory mobile phone due to its photo effect."
2- Information sharing	

2.1 Personal stories about a product or product use	"Today, I went to an after-sales store to change my phone."
2.2 Advocating or Promoting other products of the same company	"Huawei will launch a new product with curved surface soon."
2.3 Sharing community norms and functionalities	"Community norm: The member level and required points in the Huafen club."
3- Information seeking	
3.1 Questions about community life	"Is there an administrator? Is this picture against the community rule?"
3.2 How to solve a problem when using a product	"My phone cannot get online. What happened?"
4- Socialization	
4.1 Call for group purchase, common behavior	"Are any of you interested in group purchase of Mate20 to get a better deal?"
4.2 Personal life (e.g., showing pictures that one took with his/her phone)	"Using Huawei Mate20 Pro to record my daily life!"

build a social network for the community. In the network, each node represented a community member, while a link from node A to node B indicated that member A commented on a post or comment of B. Then, we calculated in-degree (i.e., the number of links coming into a node), out-degree (i.e., the number of links outgoing from a node), and betweenness degree (i.e., a measure of the extent to which the number of times a node acts as a bridge along the shortest path between two other nodes) of each core member (Prell, 2011). A node with a high betweenness degree indicates that a member plays an important role in knowledge transfer through the community. By using the HITS algorithm (Kleinberg, 1999), we measured authorities (i.e., the nodes that most of nodes point to) and hub (i.e., nodes that point to other nodes with high authorities) scores of nodes.

Second, the numbers of posted and received comments reflect a member's influence on other community members. To investigate the influence of core members on other members and validate our clustering result, we ran a Kruskal-Wallis test regarding the numbers of posted and received comments by core members. In addition,

a post hoc analysis after a Kruskal-Wallis test was conducted to analyze pairwise group difference.

4. Results

4.1 Identification of core community members through clustering

Table 3 shows descriptive statistics of the measures of participation behavior of community members. Through cluster analysis, members of the Mate20 Series community were segmented into four clusters, including 11,113 lurkers, 1,919 visitors, 135 commentators, and 81 core members, as shown in Table 4. The average silhouette value, a measure of how similar an object is to its own cluster (cohesion) compared to other clusters, was 0.712, indicating that the generated clusters were appropriate.

Table 3. Descriptive statistics of member activities within the community

Activity type	N	Mean	Std	Min	Max
PostNo: the # of original posts made by a member	20,256	1.529	1.750	1	46
CommentNo: the # of comments made on others' posts or comments	102,643	7.748	30.871	0	751
ReceivedCommentNo: the # of comments received from others for a member	154,267	11.645	30.111	0	761
LikeNo: # of likes received from other members	4,124	0.311	2.429	0	189
Influence density: the # of comments received from other members per post	85,862	6.481	12.647	0	386
Reaction density: the # of comments made on others' posts or comments per post	50,277	3.795	11.072	0	261.5
Manager-oriented comments: the # of comments on a manager's posts	2,120	0.160	0.792	0	31
Self-oriented comments: the number of comments on one's own post(s)	15,626	1.179	4.0534	0	207

Table 4. Interactive activities of different types of community members (average value per member)

Activities	Lurkers (11,113)	Visitors (1,919)	Comm-entators (135)	Core (81)
PostNo	1.21	2.73	2.88	14.17
CommentNo	2.68	18.77	173.71	164.96
Percentage of self-oriented comments	10. 0%	9.92%	12.4%	10.6%
Percentage of manager-oriented comments	2.72%	2.10%	1.97%	0.7%
ReceivedCommentNo	3.98	43.39	34.27	272.62
LikeNo	0.14	1.02	0.65	6.09
Influence density	3.16	23.44	12.96	49.43
Reaction density	2.14	7.55	79.17	16.12

Among the generated four clusters, the largest cluster is the lurker group, which is consistent with the findings of previous research (e.g., (Crowston & Shamshurin, 2017; Füller, Matzler, & Hoppe, 2008 ; Ridings, Gefen, & Arinze, 2006). Lurkers generated the fewest posts and received fewer comments from other community members but were more prone to comment on managers' posts than other types of members. Commentators, on average, made more comments on others' posts or comments and are characterized by the strongest reaction density. Visitors generated a similar number of posts with commentators, but with few comments made on other members' posts or on their own posts. Core members, despite being a small portion of the community, contributed the majority of posts and they also received the largest number of comments and made the second largest number of comments on other members' posts or comments. Last but not least, table 5 shows that community members who generated fewer posts are more willing to participate in the activity initiated by the company while core members prefer to open their own topics. To explore what cores are contributing to the community, a deeper investigation of different types of core members is discussed later.

4.2 Different types of core members and their contributions to the community

We manfully coded the posts and comments generated by the core members in order to investigate what kinds of contributions they made to the co-creation community. Specifically, we first examined the difference ratios (i.e., equation 1) in the 12 themes shown in Table 2 between every core member's generated content vs. the average content of all core members. Then, we clustered core members based on their difference ratios into 8 core member categories, and then calculated the mean of difference ratios of all members in each theme for every core member category, which are presented in Table 5. For example, the value of 348.62% at the intersection of "Innovation Leaders" and "Innovative ideas" indicates that on average, the number of product innovation ideas contributed by the core members in the "Innovation Leaders" category was 348.62% more than the average number of innovation ideas contributed by all core members.

Table 5. Categorization of core members based on different ratios (%)

Content Themes	*Innovation Leaders*	*Brand propagator*	*Product in Life*	*Product Comparers*	*Socializer*	*Community Ambassadors*	*Product critics*	*Brand learner*
Innovative ideas related to new product design	**348.62**	-59.50	-76.86	-76.86	-79.75	-100	-87.54	-2.80
Problem report	38.46	-100	-74.29	-74.29	35.00	-80.71	**163.08**	-22
Advocating other products of the company	60.22	**420.71**	-66.94	-0.82	-42.14	-33.88	-10.99	-69.14
Product usage advice and suggestions	**94.07**	-0.41	-14.64	4.33	-66.80	-14.64	-13.18	-15.90
Socialization (e.g., group purchase)	57.74	-74.37	46.47	17.18	**117.88**	-85.35	-60.56	9.37
Personal life	-23.93	276.74	**391.11**	-73.09	-58.79	-56.27	-71.02	-56.05
Personal feelings about a product	**89.92**	-35.03	-44.31	17.57	-2.54	-78.34	56.60	-30.70
Personal stories about a product or its use	43.79	-82.69	-40.66	28.57	-13.46	-75.27	1.18	**66.15**
Information seeking related to product use	51.63	-73.12	-59.04	-7.84	**65.76**	-92.32	15.79	43.36

Discuss or share other companies' products	60.22	131.43	-66.94	***230.61***	6.07	-66.94	-40.66	-69.14
Questions about community life	24.62	-100	-100	15.71	1.25	-100	**86.92**	62
Sharing community norms and functionality	-10.99	-100	65.31	-100	-100	**313.27**	-100	-100

Based on the differences in contributions, we categorized core members into the following eight groups, including:

1) *Innovation leaders* (13 members) play a leadership role in product innovation in the co-creation community. They are featured by contributing a dominant number of posts and comments related to product innovation, including posts and comments on new product ideas, product problems, product usage suggestions, and information about products of competitors, which can enable Huawei to incorporate some innovative ideas into future product design and improve product quality to better meet consumer needs. They are the drivers of co-innovation who also provide the largest number of comments. The following are examples of posts from innovation leaders:

"In short, I would recommend to add a password when turning off a phone so that in case the phone is stolen, I can still trace its location…"

"I think the phone should add a function that can display the battery level…"

2) *Brand Propagators* (4 members) are eager to promote Huawei products. For example, they like to share new product information in the community. Similarly, they are also interested in keeping track of other products of Huawei's competitors. In the meanwhile, those members also actively engage in socialization activities such as sharing his personal life in the community. The following is an example of posts made by brand propagators:

"Recently, four new Huawei products received the 3C certificates from the National Quality Certification Center. They are very likely to be the P30 series that Huawei will release next month…"

3) The 7 core members in the *product-in-life* category emphasize the use of a product in their personal life, such as sharing the pictures taken by their phone. They do not often share knowledge about products or seeking for information, but they are willing to engage in discussions about community norms and functionalities. Two examples of posts made by such members are as follows:

"The most beautiful travel - with the Mate20 to visit the Forbidden City in Beijing …"

"I used my Mate20 to record the first day of work in the Chinese new year …"

4) *Product comparers* (7 members) are characterized by high expectations of products. They like to compare products of other competing manufacturers in the market against Huawei's products and provide performance and cost comparisons (see examples below). They not only seek for others' opinions about differences among different manufacturers' products, but also share their own perspectives about which product seems superior. Therefore, their contributions to the community enable Huawei to have a better and timely understanding of the pros and cons of its products in comparison to competitors' products from a consumer perspective.

"Xiaomi 9 vs Huawei Mate20 Pro in side-by-side photos …"

"Can someone tell me about the experience of using XR Series vs. Samsung S9? …"

5) *Socializers'* (8 members) main focus is to socialize with other community members. Their posts/comments are mostly oriented to all other community members but less

likely to be related to product innovation, such as:

"*Please complete a survey: do you buy broken-screen insurance and extended warranty?...*"

6) *Community ambassadors* (14 members) are members who tend to be concerned about issues regarding community norms and regulations. In addition, they are similar to innovation leaders in offering product usage advice and suggestions. For example:

"Set up HuaweiShare in ten easy steps, and say goodbye to the data line…"

7) *Product critics* (13 members) are essential to product innovation. Those members are vocal about experienced problems of products or their feelings (e.g., dissatisfaction) when using products. Therefore, they are keen to product quality improvement. For example,

"Where is the picture I just downloaded? Sometimes looking for a picture on this phone is really difficult and frustrating..."

8）*Brand learners* (15 members) are members who are relatively new to products and lack of sufficient product knowledge. Therefore, they often make posts to share their personal stories about a product or product use, hoping to get some feedback or confirmation, or seek for information or knowledge about product use from the community. For example:

"Can I ask a question: Can the Mate20p original headset be used to answer the phone?..."

Among the above core member categories, innovation leaders, product comparers, and product critics (approximately 41% of core members) are the major source for contributing to SI in the co-creation community through their posts and comments on various product-related issues, which can provide insights and ideas to manufacturers for future product design and quality improvement. Those three types of innovation-driven core members focused on different yet complementary issues related to products.

For example, innovative leaders mainly concentrated on new ideas for products, while product critics focused on reporting problems and sharing their emotions about products. Indeed, in Schatzki' practice theory (2002; 2015), emotions are involved in activities that compose practices.

4.3 *Influence of different types of core members on other members to contribute to innovation co-creation*

4.3.1 Social network structure

We calculated several centrality measures of the community network as described in Section 3.2. As shown in Figure 2, the innovation leaders possessed the highest indegree and outdegree, indicating that they were highly followed by other members in the community. The innovation leaders not only made the most innovation related posts and comments than any other types of core members, but also received many follow up comments from other community members, showing that innovation leaders indeed play a key role in innovation.

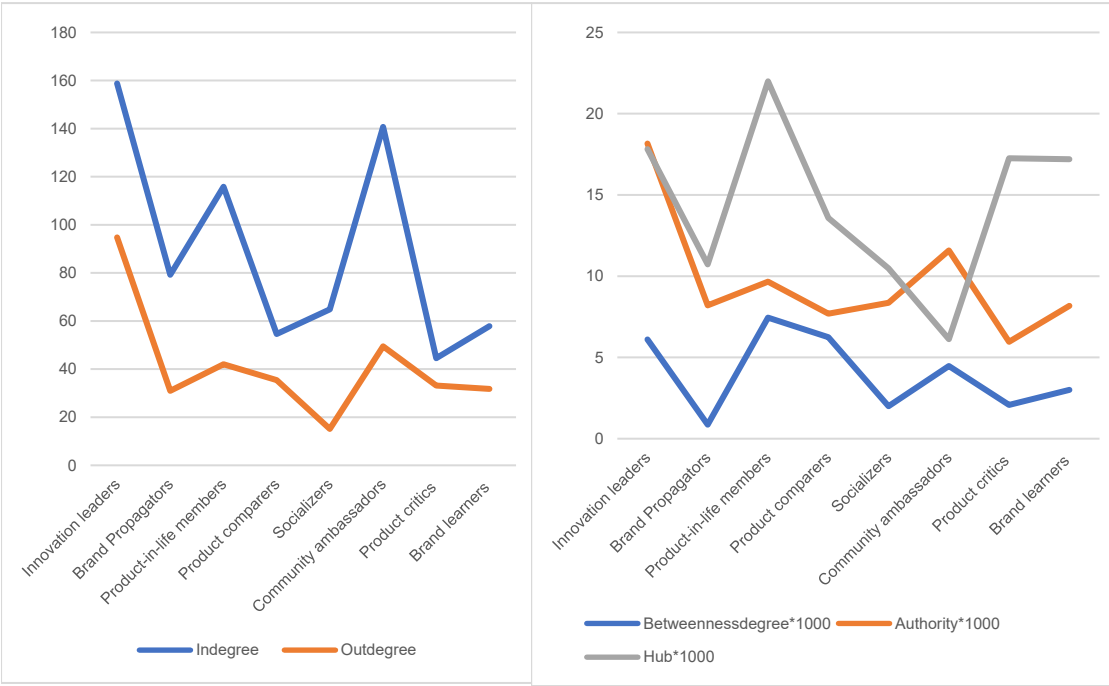

Figure2. Community network centrality measures of different core members

While community ambassadors ranked the second in terms of indegree, they were characterized by a relatively low outdegree. In contrast, product critics had the lowest indegree and a relatively low betweenness degree, indicating that the problems they reported did not receive many comments from other members. There might be multiple reasons for this phenomenon. For example, some problems may not be perceived as problems, or not have been experienced, by other members. The product-in-life members, because of the high betweenness score, can be viewed as community gatekeepers, while socializers, surprisingly, had the second lowest betweenness score.

In general, the innovation leaders and community ambassadors seem to have the largest impacts on other members' behaviors in the community (i.e., the way to participate in co-creation process), which is manifested by the significantly higher indegree scores than other types of core members.

4.3.2 Activity of core members

It is common that peripheral members of online communities tend to generate content infrequently (Crowston & Shamshurin, 2017; Gong, Lim, & Zhu, 2015; Perna, Interdonato, & Tagarelli, 2018). Because different types of core members have different motivations and concentrate on different issues, their behaviors in a community vary as well, which may exert different influence on other members.

Previous research has suggested to use the number of received comments as an indicator of one's influence in an online community (de Vries, Gensler, & Leeflang, 2012; Pletikosa Cvijikj & Michahelles, 2013). The activity of making a comment by a core member can be perceived as calling for reciprocity (Pai & Tsai, 2016; Zheng, Li, Wu, & Xu, 2014), which can facilitate knowledge sharing. According to Pesämaa, Pieper, Vinhas da Silva, Black, and Hair (2013), the willingness to share knowledge is moderated by self-efficacy and community receptivity and can enhance personal interactions and benefit community cohesion. It is widely recognized that knowledge sharing is a kind of prosocial behavior (Ray, Kim, & Morris, 2014). Once other

members see valuable posts and comments from core members, they will feel gratified and likely provide comments in return (Yang & Li, 2016).

Drawing on previous literature and the context of this study, for each type of core members, we used the number of comments received from other members and the number of comments made on other members' posts as measures of their influence on other members' activity (Table 6). The larger the number of comments on a core member's post, the more significant the influence of that member on the rest of the community.

Using RStudio, we first conducted a Shapiro-Wilk test to check the distributions of the number of comments made on other members' posts ($W=0.824$, $P<0.001$) and the number of comments received from others members ($W=0.87$, $P<0.05$). Due to their non-normal distributions and the small and different size of each core member group, we performed a Krsukal-Wallis non-parametric test to examine whether there existed significant differences in the number of received comments from other members and different core member groups. Results showed a positive effect of the number of received comments from other members ($\chi^2(7) =29.233$, $p<0.001$) and comments made on other members' posts ($\chi^2(7) =14.203$, $p<0.05$).

Table 6. Impact of core members

	# of Comments made on other members' posts/person		# of comments received from other members/person	
	Mean	Standard deviation	Mean	Standard deviation
Innovation leaders	233.00	247.39	419.69	212.20
Brand Propagators	166.00	173.07	335.00	89.83
Product-in-life members	203.86	148.64	218.43	103.07
Product comparers	133.71	102.48	225.57	132.29
Socializers	75.25	66.48	214.00	79.28
Comm. ambassadors	110.64	196.68	364.64	129.21
Product critics	185.62	116.81	209.00	89.23
Brand learners	182.80	160.48	176.27	70.98

Then we ran a pair comparison test. We aimed to see whether the three types of core members who mainly focused on innovation (i.e., innovation leaders, product comparers, and product critics) differed from other types of core members who paid less attention to innovation (i.e., brand propagators, product-in-life members, brand learners, community ambassadors, and socializers). For the sake of simplicity, the other five categories of core members who paid less attention to innovation are collectively referred to as "*other contributors".* There were significantly more comments on innovation leaders' posts than on those of product comparers ($p<.05$), product critics ($p<.05$), and other contributors ($p<.05$), implying that innovation leaders had higher influence on other members than other three groups. On the other hand, product critics, product comparers (p=n.s.), and other contributors received similar numbers of comments from others (Table 7). In addition, there were no significant differences in the numbers of comments made on other members' posts or comments among those groups.

Table 7. Pairwise comparisons of the numbers of comments received

Pairwise comparisons	**Mean differences**
Innovation leaders - Other contributors	162.817**
Innovation leaders - Product comparers	194.121**
Innovation leaders - Product critics	210.692**
Product comparers - Other contributors	-31.303
Product critics - Other contributors	-47.875
Product critics - Product comparers	-16.571

**: $p<0.01$

5. Discussion

5.1 Major findings

The main objective of this study is to explore different behaviors of core members in a Chinese online co-creation community, as well as differences in their contributions to social concerns and in their impact on the behavior of other members in the

community, which has never been investigated before. To achieve those goals, we conducted a three-phase approach guided by UGT and Practice Theory that integrated analysis of posting activities, content posted, and community network structure. By using the real-world data collected from the Huafen online community in China, we first found that core members are more dependent on other community members and in some cases may have little connection with the host company compared to other members who generate few messages. Then we identified 8 types of core members that concentrated on different issues motivated by different interests. The developed typology includes innovation leaders, brand propagators, product-in-life members, product comparers, socializers, community ambassadors, product critics, and brand learners (see Table 5). Among them, innovation leaders, product comparers, and product critics are the major contributors to the SI process. They often took initiatives in making posts on product-related issues. In the meantime, their posts and comments also incurred a lot of follow up comments from other community members. So, they not only led the SI process, but also influenced other community members. It reveals that different core members have different impacts on other members. For example, the average number of comments made by other committee members on innovation leaders' posts was significantly larger than that of other non-innovation types of core members (i.e., brand propagators, product-in-life members, brand learners, community ambassadors and socializers). Meanwhile, we also found that innovation leaders received significantly more comments from other members than product critics and product comparers. However, the product critics and product compares received nearly the same number of comments from other members, meaning that they had similar impact on other members. These results together demonstrate that different types of core members, in particular those who focus on SI, may exert different impacts on other members' contribution to community.

Several studies have analyzed the behavior of community members in online communities (Akar et al., 2019; Benamar et al., 2017; Fuger et al., 2017; Füller et al., 2014; Guo et al., 2017; Kou et al., 2018; Pfeil et al., 2011)and found similarities

between different research context (Fuger et al., 2017). The question arises whether a company-hosted online co-creation community focusing on SI appears to have different user types. Thanks to the novel user topology, some user types identified in our study show somewhat similarities with previous studies whereas other types can only be found in the given context of COCC. For example, previous literature defined leadership role in co-innovation as *project leader* (Guo et al., 2017), *collaborator* (Fuger et al., 2017), or *master* (Füller et al., 2014), who shares his expertise and interact actively with other community members. However, previous research has never distinguished *innovation leaders, product comparers,* and *product critics* according to the innovation types. The *innovation leaders,* an essential role for the social or the health condition of a community, do well in all disciplines. The *innovation leaders* possess novel thoughts and focus on the potential needs of other community members. *The product critics* can be compared to incremental user innovation type, identified by Nielsen et al. (2016), who seek to improve the existing products or services(e.g. energy efficiency). *Product comparers* participate in the SI process in a unique way by sharing and comparing information about other products of competitors in the same industry. They not only serve as a bridge among other communities in the society but also drive the participation of other members as well. A similar user role could not be found in existing literature. We assume the *product comparers* unique behavioral patterns strongly relate to the COCC context. *Socializers'* main focus is mostly oriented to socialize but less likely to be related to innovation. Surprisingly, different from *socializers* identified by Füller et al. (2014) and Akar et al. (2019) , in COCC context, *socializers* only interact at a moderate level. In contrast, the *product-in-life* category who emphasize the use of product in their personal life are of special value for community because their high betweenness degree improve social sustainability of the community. *Brand learners* are members who are relatively new to products and lack of sufficient product knowledge. The *brand leaners* can be related to passive designer (Guo et al., 2017) or learner (Kou et al., 2018). *Community ambassadors* are members who tend to be concerned about issues regarding community norms and regulations as

well as product usage suggestions. Their focus is potential need of other community members. A similar user role can be compared to the generalist (Benamar et al., 2017) or *central supporter* (Pfeil et al., 2011). *Brand Propagators* are eager to share product information about hosted-company in the community. They interact and submit ideas at a lowest level among the core group. A similar user role could not be found in existing literature. Similar to Fuger et al. (2017), we could not find a user type focusing only on contributions as mentioned in Füller et al. (2014) . Most core members participate in all activities within COCC context.

5.2 Limitations and future research

This study bears some limitations that offers future research opportunities. First, user participation is a major factor in SI process, however, SI may also be affected by other factors such as platform construction and knowledge diffusion (Kruger et al., 2018). In our study, we only investigate sustainable user innovation types in social aspects. Future research could integrate our results with other relevant factors to build a holistic business model for SI. Second, given the scope and complexity of the study, we only collected data from an online co-creation community owned by one Chinese company. Nielsen et al. (2016) posited that one stream of researchers should be aware of other researchers who cover the similar topics. Although conceptual differences do exit, for example, the literature on sustainable home energy technologies could garner insights from sustainable user innovation in an online community(Hyysalo et al., 2017). It would be beneficial if future studies could validate the findings and methodology of this research by using data collected from other environments. Third, this study focuses on co-creation in China. Research has shown that cultures have influence on individuals' behavior in a group environment (D. Zhang, Lowry, Zhou, & Fu, 2007). It would be essential to investigate if community members with different cultural backgrounds may be more likely to be a certain type of active member. In addition, it would be interesting to expose the context of freedom of expression (or its limitation) in the host country of the online platform given the different levels of network regulation in different regions.

6. Conclusion

The case we investigated represents a best practice example of sustainable user innovation. Different to the often-mentioned crowdsourcing community, users in COCC not only seek an advance in products and services for economic performance but also meet social criteria as well. This paper highlights the importance of core member investigation in order to improve the sustainability of online communities. In the digital era, practitioners would also benefit from exploring the behavior of core members by using a global approach consisting in identifying member roles through their activities, shared content and social position in the network.

From an academic perspective, this research makes three novel research contributions. First, it has been shown that an online community typically consists of a small but active member group and a larger number of passive, peripheral members (Fuller, Jawecki, & Muhlbacher, 2007; Toral, Martínez -Torres, & Barrero, 2010; Ye & Kishida, 2003). Most of previous studies focused on differences between core and peripheral members. The full potential of co-creation within sustainability remains less explored (Nielsen et al., 2016). Little is known about whether there are different types of core members and whether they contribute to the potential needs of others including social concerns, especially from a COCC perspective, in different ways. This research identifies active members of a community through clustering analysis, then proposes a method that relies on a set of coding schemes developed based on UGT and a distance ratio measure to develop a novel topology for core members of COCC. Second, the developed typology consists of 8 types of core members. Based on the typology, we can easily identify the types of core members that are co-innovation oriented, achieving a deeper understanding of core members in an online COCC context. Our developed typology also advances in scientific knowledge by showing dissimilates with previous studies. For example, previous research has never distinguished *innovation leaders, product comparers,* and *product critics* from other core members. We also assume the unique behavioral patterns of *product comparers, socializers* and *brand propagators* strongly relate to the COCC context. Third, this study extends previous work by

providing a new dimensional view of internal dynamics in a COCC context through investigating the influence of different types of core members on other members in a COCC context on the basis of Practice Theory. Specifically, we use the number of follow-up comments on core members' posts as a measure of their impact on other members. The results show that different types of core members have varying levels of influence on other members, which has rarely been studied in the literature.

From a practitioner's perspective, the findings of this research also provide a number of practical implications that can address social concerns better and more effectively. For example, the company may give greater freedom when assigning tasks thus allowing cores to freely play their own strengths and to drive the participation and knowledge contribution of peripheral members to sustain innovation; may consider offering incentives and recognition to those innovation leaders who generate the best and/or most innovation ideas that benefit new product design and product critics who identifies critical flaws or problems of products that lead to product quality improvement. Through co-innovation of knowledge between companies and innovation-oriented users, company may increase the capabilities of the innovations and improve their sustainability; may support product-in-life members to organize photography competitions that demonstrate the better use of products in daily life, or provide better, richer communication tools in the online community that enable socializers and community ambassadors to maximize their roles in keeping the community cohesive and interactive, and/or ask brand learners to help develop a product Q&A session that can benefit other new consumers. Finally, it is claimed that the resources of SI not only come from customers but also from competitors and other stakeholders(Boons & Lüdeke -Freund, 2013). Therefore, the community should not censor or discourage product comparers as their posts may help manufacturers identify the relative pros and cons of their own products in comparison to competitors and look for solutions to address those cons.

Company-hosted online co-creation communities are increasingly popular nowadays as a promising platform for companies to connect to their users or consumers,

advertise their new products, allow consumers to provide peer support, and more importantly, provide a venue for involving consumers in the co-innovation process so that products can be continuously innovated and competitive.

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