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Understanding Information Sharing Among Scientists Through a Professional Online Community: Analyses on Interaction Patterns and Contents

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ABSTRACT
Even through many professional organizations increasingly use Q&A sites in their online communities for information sharing, there are few studies which examine what is really going on in the Q&A activities in professional online communities (POC). This study aims to examine the interaction patterns and contents posted in the Q&A site of a POC, KOSEN, a science and technology online community in South Korea, focusing on how actively scientific information and knowledge are shared. The interaction patterns among the participants were identified through social network analysis (SNA) and the contents in the Q&As were examined by content analysis. The results show that the overall network indicated a moderate level of participation and connection and answerers especially tended to be active. Also, there are different interaction patterns depending on academic fields. Relatively few participants were posting leaders who seemed to steer the overall interactions. Furthermore, some content related to manipulation and explanation for experiments, which are in urgent need, seem to be posted in the sites more frequently with more amounts. Combining both SNA and content analysis, this study demonstrated how actively information and knowledge is shared and what types of contents are exchanged. The findings have practical implications for POC managers and practitioners.

Keywords: information sharing, professional online community, interaction pattern, SNA, content analysis, KOSEN

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1. INTRODUCTION

With the help of recent information communications technology, it is now common for science and technology researchers to form a professional online community (POC) and to share information. One major activity in POCs is posting questions and answers (hereafter Q&A) related to their scientific interests. The Q&A platforms have in common being a conduit through which social interaction, cooperation, and learning practices are conducted by people who do similar jobs in order to cope with common difficulties and drive organizational innovation (Cranefield & Yoong, 2009; Rosenbaum & Shachaf, 2010; Tseng & Kuo, 2014, Hung, Lai, & Chou, 2015).

The popular use of Q&A activity in POCs can be derived from the fact that empirical methodologies such as experiments, investigations, observations, and surveys are widely accepted in science and technology research. Performing research with empirical methodologies frequently involves trial-and-error experiences, which can be shared with other researchers in order to mitigate unnecessary time and effort. Tips and skills gained during the research process can also be shared to optimize the process. Traditional offline communities have been very popular channels for sharing the know-how, information, and knowledge used in job 'research,' which includes a wide variety of tasks. At present, certain channels have evolved into POCs with information communications technology, urging more interactions, including POC Q&As.

Recent studies have shown some differences in interaction characteristics between POCs and typical online communities. Emotional online communities show substantially active interactions within cliques, or sub-networks, but participants in technology-focused online communities and POCs have more reciprocal tendencies (Pfeil & Zaphiris, 2009; Faraj & Johnson, 2011). One study focused on the implications of POC interactions, where the contents of individual community participants have been accumulated, accessed, and reused. Scientists and engineers can seek information and solve problems from POCs (Chiu, Hsu, & Wang, 2006; Wang et al., 2015). Supporting platforms which permanently enable access and curating accumulated intellectual assets from POCs are considered to be appealing policies for government.

Many previous studies on Q&A activities of general online communities such as Yahoo Answers and WikiAnswers have been conducted. These studies have tried to reveal the motivations (Choi & Shah, 2016) and characteristics of an individual participant in transferring information and knowledge (Chiu, Hsu, & Wang, 2006; Chen, 2007; Lai, Chen, & Chang, 2014; Hung, Lai, & Chou, 2015). Although professional online communities are growing rapidly, there are few studies focusing on information sharing through the Q&A activities in POCs. Professionals may show different information or knowledge seeking and sharing behavior since they have stronger learning motivations than common people do (Wang et al., 2015; Faraj & Johnson, 2011; Hung, Lai, & Chou, 2015).

The purpose of this study is to investigate the degree and quality of information sharing in the Q&A activities of a POC. In order to achieve this purpose, this study firstly examines the interaction patterns through social network analysis (SNA), and also closely examines what types of contents are shared in the Q&As by using content analysis.

KOSEN (the Global Network of Korean Scientists and Engineers) was chosen as a typical example of POCs. It was financially supported by the Korean Ministry of Science and Technology, launched in 1999. Specifically, this study focuses on the analysis of interaction patterns and contents in the 'What is?,' a Q&A website of KOSEN, where Korean scientists and engineers can ask each other for help tackling complicated problems.

The Q&A site in KOSEN, 'What is?', curates an 'as is' like chatting room for showing the questions associated with research and employment fields. KOSEN and Yahoo Answers are similar in that both have a Q&A format which facilitates interactions between users, while 'What is?' in the KOSEN as a POC is more specific, providing in-depth information, because this concept involves questions on experiments, investigations, observations, and surveys among professionals. In this regard, it is similar to Wikipedia considering the content lifecycle of creation-development-completion, as the continuous accumulation of contents is achieved. Other members add related contents to improve the posting after the initial member posts problem-solving content. Additionally, all members, including the questioner, can reply and view and can even click a 'like'

button, which can be considered as an evaluation of the contents (Kim & Yoon, 2011; Luarn, Lin, & Chiu, 2015). Therefore, the Q&A site of KOSEN can be a typical example to investigate how academic and scientific information and knowledge is shared among research professionals.

Using social network analysis (SNA), this study analyzes the log files of the KOSEN 'What is?' website in 2015. These log files were gathered by a software crawler program, which is based on Python Beautiful Soup Library. SNA is used to elaborate social interactions or collective behavior within the POCs (Hasmuni, Sulaiman, & Zaibidi, 2014), with implications affecting a clear understanding of the relationships among members of POCs and of managing POCs successfully. Also, the content analysis of the questions and answers uploaded in the POC will help to understand the depth of information and knowledge shared among professionals.

Previous studies about Q&A habits in online communities showed relationship length/volume of postings and the type of issue (Baek & Kim, 2015), academic fields (Ademic et al., 2008), and occurrence of replies (Joyce & Kraut, 2006). Thus, it will be helpful to explore the participants' activity or behavior if we were to measure the thread length and post length. The study proposes the following research questions:

RQ1: What are the interaction patterns and network structures of the participants in the Q&A activities of a POC?

RQ2: What are the types of questions and the thread and post lengths of the contents created by participants in the Q&A activities of a POC?

This study has practical implications for online community practitioners who wish to facilitate virtual information sharing in POCs.

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1. Interaction Patterns and Information Sharing in POCs

Previous studies have revealed that professionally-oriented online communities have distinctive characteristics, including interaction patterns. Interaction patterns in five online communities in technology fields are characterized by direct and indirect reciprocity rather than by preferential attachment patterns (Faraj & Johnson, 2011).

Also, it was found that there is a typical core-peripheral structure in online professional communities consisting of school teachers, who form a dispersed network in interaction (Zhang & Liu, 2014). In the community, core participants are teaching assistants and part-time teachers, while teachers were usually peripheral. Researchers found that the majority of core individuals were at the knowledge-deploying level and that only a few reached the knowledge-creating level.

Several researchers have hit their stride in studies of online communities using SNA at present. Studies using SNA can demonstrate a whole network structure with visual graphics and identify who is central in the network, and what key players or ties are vital to monitor (Wasserman & Faust 1994; Zhang & Liu, 2014). Compared to studies using a participant's perception data from a survey or interview, SNA has the potential to explore the dynamics of online communities by analyzing the real interaction data accumulated in the network. Studies using SNA have tried to show the interaction patterns within a network of the users. These studies have demonstrated how information and knowledge are shared by professionals through the online activities.

Focusing on online discussion in teaching environments, Zhu (2006)'s study identified two types of interaction occurring during online discussion: star and interconnected web. The star type of interaction is centralized by one person, who proposes discussion topics or questions. On the other hand, the interconnected web type of interaction shows multiple points of centrality. The study concluded that the interconnected web type seemed more conducive for collaboration and knowledge construction. But the study claimed that the active interaction type can occur by an instructor's course/discussion design rather than by online environment.

Related to scientific collaborations, Hossain and Fazio (2009) and Bozdogan and Akbilgic (2013) analyzed the levels of scientific collaboration between different subject fields using SNA. The results showed that collaborations between scientists increased for almost all subject fields. Especially, some academic fields

such as nuclear, energy, and environment subject fields play a key role in the network in the level of scientific collaboration. Bozdogan and Akbilgic (2013)'s study showed that interactions between subject fields such as particle acceleration–physics, nuclear–energy, and nuclear–physics have increased.

Also, studies based on SNA have identified individual key players in online communities using several centrality measures. Hasmuni, Sulaiman, and Zaibidi (2014) analyzed weblogs using degree centrality and betweenness centrality measurement in SNA. They examined the strength relation and identified influential webloggers within the network. Baek and Kim (2015) explored the dynamics of an online community by examining its participants' centrality measures: degree, closeness, and betweenness centrality. The results showed that all three centrality measures of an individual participant in previous time periods positively influenced his/her information sharing activity in the current time and following time periods.

Most recently, Li et al. (2016) explored the levels of participation and patterns of interactions among health professionals in a large online professional learning network. SNA results showed that their learning network is highly centralized and loosely connected. They also found that a low level of participation occurred in general and a small set of users such as moderators and core members dominated the structural patterns of interaction.

Previous studies employing SNA have demonstrated interaction types and patterns in different professional groups such as teachers, scientists, and health professionals. These studies revealed that interaction patterns in POCs are partially effective for knowledge sharing depending on academic fields and users' participation levels. Thus, focusing on Q&A activities of a POC, this study explored overall network structures and specific interaction patterns by disciplines.

2.2. Contents in the Q&As of a POC

Interaction between participants appears to be affected by missions and contents of online communities as well as by other factors including the age or occupation of members. A recent study (Baek & Kim, 2015) found that there are two different patterns of social interactions in online communities whose topics are about personal matter or social issues. The study concluded that personal interests showed very stable and strong interactions while social issues fluctuated and showed weak interactions over time.

But there are few studies examining the relationships between contents and interaction patterns in the Q&A activities of a POC. One study showed that the length of the Q&A part on general online communities can vary depending on the characteristics of the contents. For example, the 'Yahoo Answers' Q&A of Yahoo had exchanges with a great deal of diversity of technical knowledge, advice, opinions, and support. Specifically, there were typical levels of depth and complexity of questions according to the categories, with this also applying to the characteristics of the contents (Adamic et al., 2008). For instance, posts in chemistry and physics tend to receive few replies, but those replies were relatively lengthy. All of the mathematical subcategories showed relatively low reply ratios (Wang et al., 2015). The results of this study imply that there are patterns in the characteristics of each field in the network, such as the average thread length and average post length.

Another study attempted to identify patterns of interaction of actors through the analyses of six public newsgroups; it explored accusations between responses to posts by newcomers and the continuation of participation according to a content analysis (Joyce & Kraut, 2006). Approximately 61% of newcomers received a reply to their first post, and they were 12% more likely to remain in the community than those who didn't get replied to. According to that study, the length of the message affected whether a reply was received. Replies were also found to lead to additional postings.

Wang et al. (2015) identified the effectiveness of information sharing by measuring communication patterns, or online discussion threads. Their study sorted discussion threads into three types: unhelpful, helpful, and solved threads, and found that effective information sharing accompanied a longer thread length.

Conducting content analysis, this present study examines what types of contents are actively shared through the Q&A of the POC by discipline and category.

3. DATA COLLECTION AND METHODS

This study collected 564 questions and 1,847 replies as posted in 2015 on the KOSEN 'What is?' website us-

ing web crawling software developed by ourselves. On the KOSEN 'What is?,' questioners choose from one of 20 disciplines and then adequately input the proper keywords describing the question. Consequently, the discipline and keywords for each question are posted in a complete form, simplifying data acquisition in this study. After reviewing the collected questions, we found that many questions were skewed to a few particular disciplines, i.e. chemistry, which was not evenly distributed among the 20 disciplines. Thus, this study analyzed the content categories for the questions and replies of six major disciplines. Only simple descriptive statistics were calculated for other disciplines.

First, for the purpose of identifying interactions among the participants, this study verified whether or not messages were posted between a questioner and an answerer. It can therefore be regarded that interaction may clearly occur if both the questioner and answerer had one or more postings. In detail, a square matrix was created using the ties of the questioner ID and the answerer ID in such cases, and an SNA was conducted using the matrix via Netminer 4.0. The number of views and clicks of the 'like' button was noted and then excluded in the SNA, as this study focused on interactions, i.e., relationship links, between the questioner and the answerer.

SNA analyzes relational patterns of nodes (actors) and connections (ties) based on mathematical computations. Its structural network parameters like centrality show characteristics of network activity, social roles, positions, and associated social mechanisms like power and dependency (Wasserman & Faust 1994).

Thus, the factors of major indicators such as the size of the network, the number of links, degree centrality, and network density were calculated to understand the links and interactions among the participants. The size of the network refers to the total number of participants in the network, and the links refer to the number of relationships between participating members. Degree centrality is the sum of the connections from/to a certain participant, which shows the location of the member in the network. The higher the degree is, the more ties there are from one member to others. Network density represents the number of actual ties in a network compared to the total number of ties that the network can contain overall. A higher network density indicates the rapid diffusing of messages.

Second, in conducting content analysis this study categorized questions after reviewing their title and content carefully in each case. Content analysis is a research technique for objective, systematic, and quantitative description of the manifest content of communication (Berelson, 1952). For this reason, the 'What is?' did not provide a category of questions on the website. After reviewing one hundred questions as a preliminary investigation, seven categories were established to classify the questions. These were 'manipulations,' 'materials,' 'equipment,' 'outsourcing,' 'explanation,' 'references,' and 'standards.' Though two coders categorized the questions according to the seven clear categories, 184 questions did not coincide with these categories. For these, one of the authors finally determined their categories.

After categorizing the content of the Q&As, the thread length and post length are calculated. Thread lengths were counted as the frequency of replies plus that of comments, and the post lengths were counted as the number of syllables in replies and comments. The What is? Q&A posts were written in Korean. When it comes to post length, length in Hangul, the Korean alphabet, does not mean the number of letters as in the Latin alphabet. According to Taylor (1980), "Hangul letters are grouped into blocks, such as 한 han, each of which transcribes a syllable. That is, although the syllable 한 han may look like a single character, it is actually composed of three letters."

4. FINDINGS

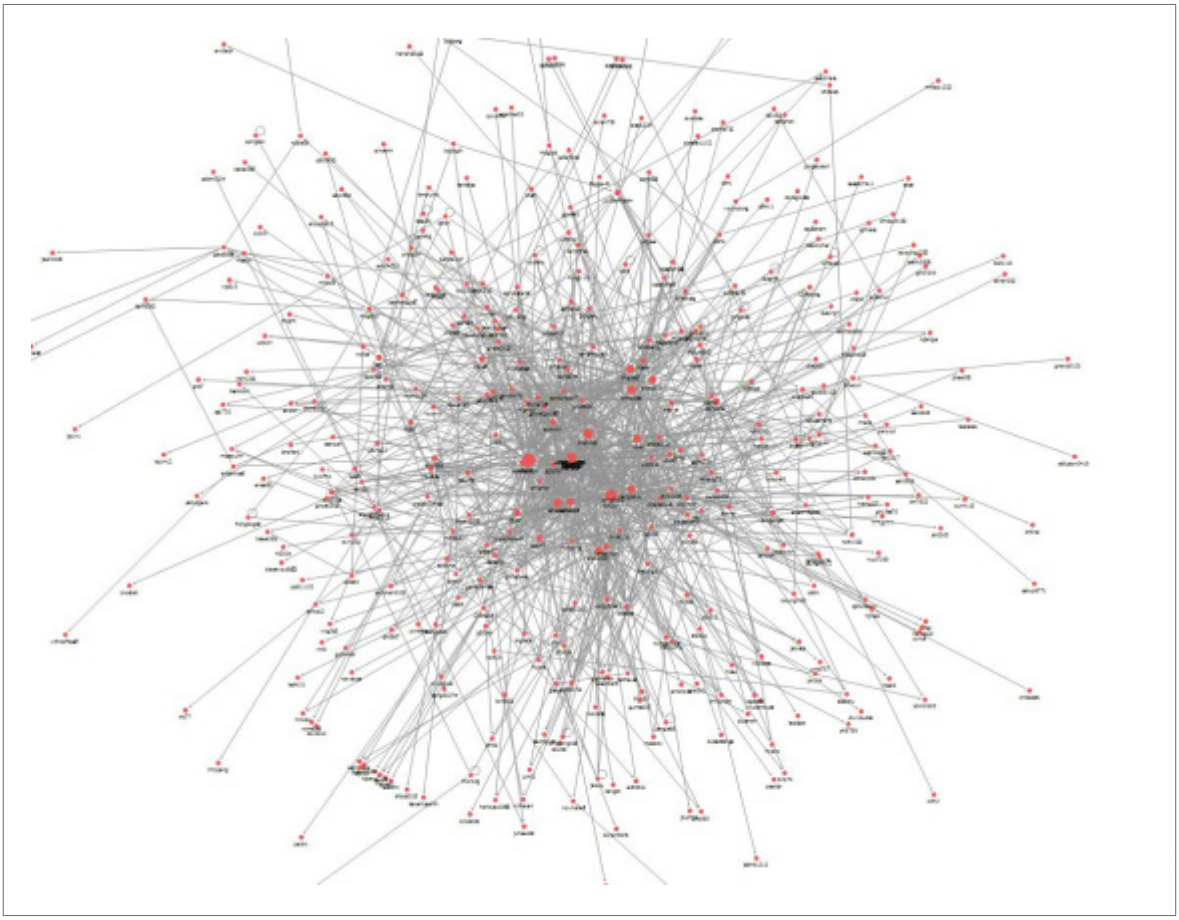
4.1. Overall Network Structure in the Q&A Site

The SNA showed the overall structure of the network including all interactions, as shown in Figure 1. Here, 395 participants in the network posted 1,102 links, and their average degree score was 2.572. In the network there were 109 links, with the degrees equal to three or more and accounting for 9% of all links. The density, 0.007, was calculated based on actual links divided by all possible links. These overall network structure measures indicate a moderate level of participation and connection among the users in the network. Reciprocity, the degree of mutual interactions of an individual participant, was 0.085, while the transi-

tivity, the connectable possibility based on actual connectivity among participants, was 0.24. A diameter of 6.00 and mean distance of 2.17 indicates that the users are not very close to one another, which confirms the low density of the network, meaning that users may not easily reach each other and share knowledge. The in-centralization index was 19.193% but the out-centralization index was only 5.961%, indicating that answerers more than questioners tended to be active.

4.2. Interaction Patterns by Disciplines in the Q&A Site

After looking at the overall structure of interaction patterns in the Q&A activities of KOSEN, specific interaction patterns by discipline were investigated by SNA. The SNA socio-grams show more detailed pictures on the interaction patterns by discipline (Figure 2). Based on incoming connection, which is known as in-degree centrality, Figure 2 visually shows the activi-



Number of actors = 395
Number of links = 1,102
Average degree = 2.572
Density = 0.007

Reciprocity = 0.085
Transitivity = 0.24
Centralization index = 19.193% (in)
5.961% (out)

Mean distance = 2.336
Diameter = 6

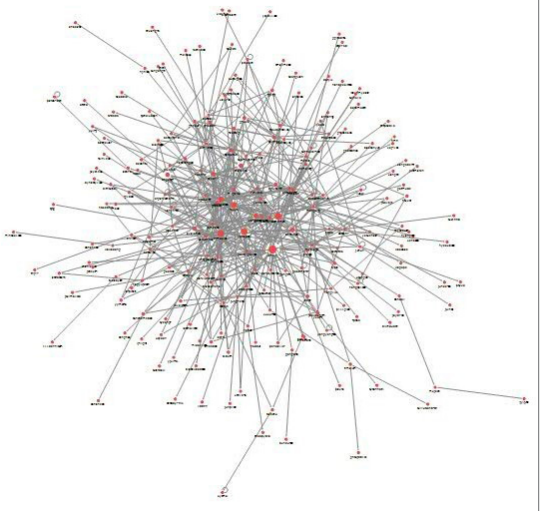
Fig. 1. Overall interactions among Q&A participants

ty and interactions of answerers. Most disciplines show higher in-degree centralities than out-degree centralities, meaning that answering activities are more active than questioning ones.

But the study found that there are different interaction patterns depending on discipline. The most active field was chemistry, with high centrality of answerers, including a few key posters whose centrality scores reached 0.197. The form of the network showed a reciprocal pattern, with the overall distribution including many participants, not swayed by a few key participants. The results indicated that the field of chemistry influenced the whole network structure of the Q&A site.

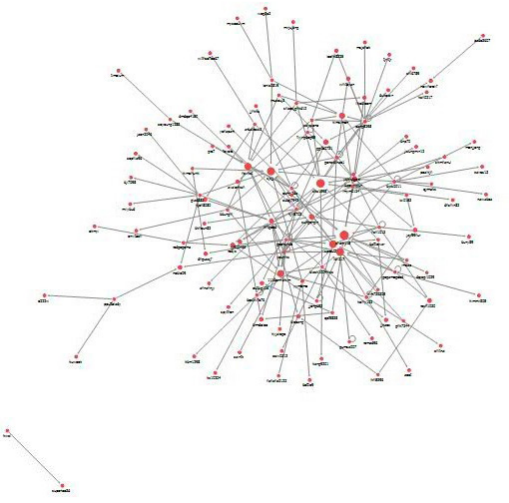
Yet SNA by discipline revealed that there are different patterns of interactions according to academic fields. Compared to academic fields with relatively high active participation such as chemistry and life science, disciplines with low participation showed that two or three questioners or answerers dominated interactions through the Q&As. In materials science, the activity of several leading members was most apparent; specifically, the centrality of the most active member was 0.286, but the reciprocity was higher compared to those of other fields. The network structure for electronics showed inward centrality, including many questioners and a few answerers, and the centrality of the most active member was 0.255. The activity of questioners more than answerers was also notable in the field of physics. In this field, the centrality of questioners was 0.368 while that of answerers was only 0.180. Health science had lagging answerers while having active questioners, though the centrality of questioners was a relatively high 0.441. This results confirmed that lower participation fields seemed to be centered by small numbers of members while more active fields seemed to be interconnected with reciprocal interaction patterns with each other.

Chemistry



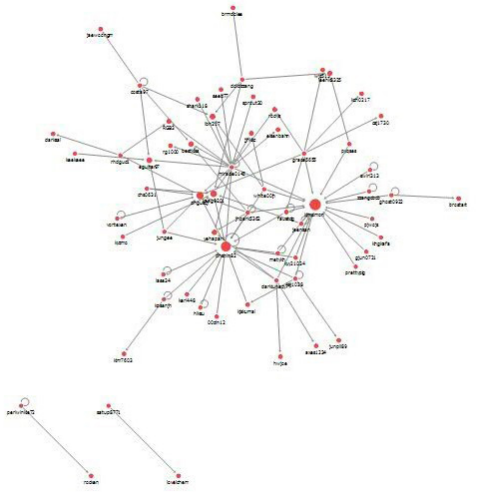
Number of actors = 209
Number of links = 517
Density = 0.011
Reciprocity = 0.037
Centralization index = 18.695% (in)
10.482% (out)

Life science



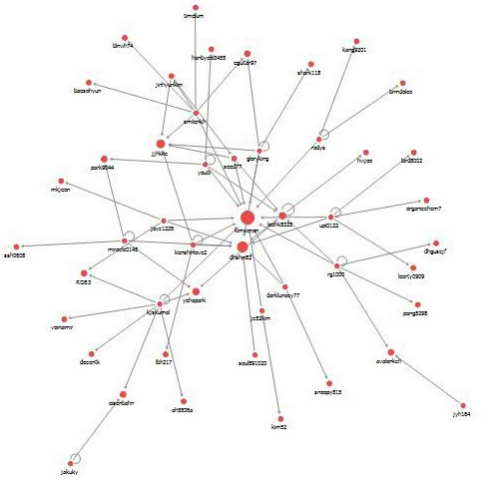
Number of actors = 117
Number of links = 203
Density = 0.014
Reciprocity = 0.04
Centralization index = 9.906% (in)
9.906% (out)

Materials science



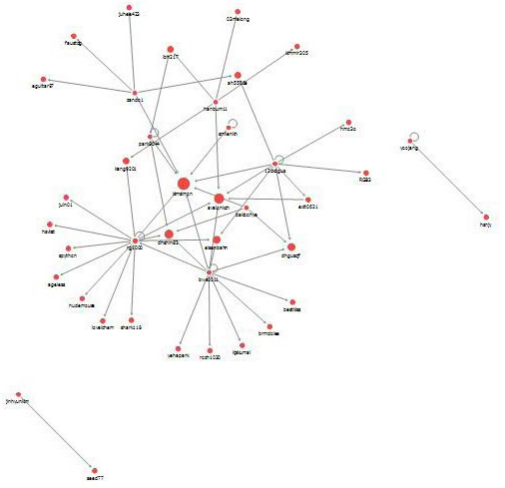
Number of actors = 64
Number of links = 105
Density = 0.076
Reciprocity = 0.076
Centralization index = 26.783% (in)
23.558% (out)

Electronics



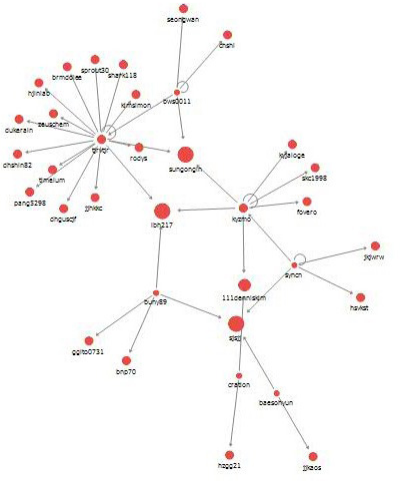
Number of actors = 48
Number of links = 74
Density = 0.028
Reciprocity=0.068
Centralization index = 23.178% (in)
12.313% (out)

Physics



Number of actors = 40
Number of links = 57
Density = 0.033
Reciprocity=0.053
Centralization index = 15.056% (in)
28.205% (out)

Health science



Number of actors = 35
Number of links = 41
Density = 0.031
Reciprocity=0.049
Centralization index = 5.882% (in)
42.215% (out)

Fig. 2. Interaction patterns classified by discipline

4.3. Contents and Depth in Q&A Activities

To achieve a deeper understanding on the interaction patterns generated in the Q&A sites, complimentary content analysis was conducted on content in the Q&A of the POC. It is especially important to note that the number of questions was an important factor, as posting a question created the starting point of a Q&A interaction. Table 1 shows more detailed descriptive statistics of Q&A activities by discipline.

The results showed that there are noticeable differences in the frequency of posting questions and answers depending on discipline. The disciplines which had more active interactions are shown in Table 1. Some academic fields led the interaction patterns with higher frequency of questions, with chemistry showing 49.46%, life sciences 9.93%, and materials science 9.75%. Regarding replies per question, health science ranked first at 3.95, with physics second at 3.76, life sciences third at 3.67, and electronics fourth at 3.17. Thus, in health science, small numbers of members with relatively few questions had lively interactions due to many replies.

Table 2 shows descriptive statistics of the Q&A contents sorted into seven categories. According to the results, the category 'manipulations' ranked first at 38.12%, and 'explanations' ranked second at 33.87%. The percentage of 'explanations' added to 'manipulations' accounted for more than 70% of all postings. This was followed in the rankings by the category 'references' at 11.7%.

These results indicate that Q&A interactions among POC members occurred in some limited content categories such as 'manipulation,' 'explanation,' and 'references.' It can be explained that many researchers have considerable difficulty in applying 'manipulations' and thus want to be provided with 'explanations' about

Table 1. Descriptive Statistics on Q&A Activities by Discipline

Disciplines	Chemistry	Life sciences	Materials science	Electronics	Physics	Health science	Others	Total
Questions	279	79	55	36	34	19	62	564
%	49.46	9.93	9.75	6.38	6.03	3.37	10.99	100
Replies	856	290	160	114	128	75	224	1,847
R/Q	3.07	3.67	2.91	3.17	3.76	3.95	3.61	3.45
Views	135,427	32,887	28,687	17,452	18,087	11,237	40,358	284,135
Likes	307	82	47	37	53	14	72	612

Table 2. Contents of Q&A Classified by Category

Category	Manipulation	Explanation	References	Materials	Equipment	Outsourcing	Standards	Total
Questions	215	191	66	30	29	23	10	564
%	38.12	33.87	11.7	5.32	5.14	4.08	1.77	100
Replies	736	644	215	73	91	65	23	1847
R/Q	3.42	3.37	3.26	2.43	3.14	2.83	2.3	2.96
Views	106,884	105,600	32,316	13,264	10,013	12,136	3,922	284,135
Likes	236	246	67	22	25	10	6	612

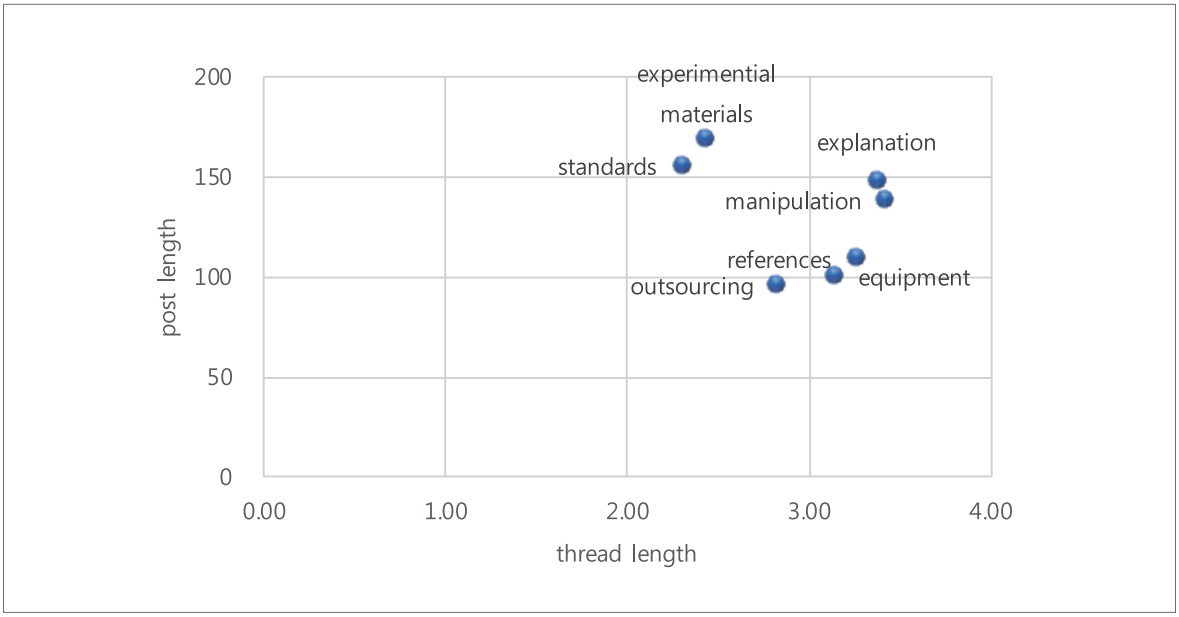


Fig. 3. Thread length vs. post length classified by content category of the Q&As

proofs of formulas or causes of phenomena. Also, the categories showing frequent questions result in relatively high responses, with manipulations at 3.42, explanations at 3.37, and references at 3.26, whereas those related to outsourcing stood at 2.83 and standards at 2.30. Interestingly, although there are more complete services for references, as noted in the menu entitled 'Request for Reference' in KOSEN, many scientists and engineers were eager to post to find references via the Q&A site as a substitute for the menu. They appear to feel that explaining exact reasons why research materials are obtained and how serious their conditions are on 'What is?' is more worthwhile than posting simply a 'Request for Reference.'

In addition, Table 2 showed that frequent question categories are relatively high in indirect interactions such as 'views' and 'likes.' The question categories with higher frequencies such as 'manipulation' and 'experiment' generated higher viewing and liking as well as direct questions.

Figure 3 shows which category of questions had longer postings in terms of thread length, including the frequency level and post length, along with volume level. The thread length in the categories 'manipulation' and 'explanation' were long, whereas that for the materials and standards category was short. The content related to experimental materials had the longest posts, while the content for outsourcing had the shortest post lengths. Q&A has the longest post lengths when urgently requesting information for an alternative during experiments. For example, "At present, we are conducting an organic reaction experiment, though the process is unable to achieve a certain O2 condition. Thus, we asked which oxidizer to use." This case fell under the in-depth interaction category, and the volume of Q&A messages, at 3,125 bytes, was high compared to those of other Q&A categories, at 147 bytes.

Based on these results, this study seemed to confirm that interaction patterns on the Q&A sites in a POC are related to contents shared. A certain academic field like chemistry and life sciences seems to exchange more information and knowledge through the Q&A sites in a POC. Also, some limited contents related to manipulation and explanation, which are in urgent need by researchers, seem to be posted in the Q&A sites more frequently with more amounts of posting.

5. DISCUSSIONS AND CONCLUSIONS

5.1. Summary and Discussion of Findings

The focus of study was on how much interactions for information sharing were generated and what types of information and knowledge are exchanged in the activities. This study collected 564 questions and 1,847 replies posted in the year 2015 in the KOSEN Q&A site 'What is?'.

First, social network analysis to identify the overall interaction patterns among questioners and answers showed an average degree of 2.572 and a density of 0.007, inferring that the overall interactions among Q&A participants were moderately active and nearly all members having sparse interactions led to a low network density (Figure 1). Based on the index of in-degree centrality, answerers were more active than questioners. These figures indicate that the links among the Q&A site participants are relatively low and sparsely knit, referring to the findings of a former study (Watts & Strogatz, 1998).

Also, the overall interaction patterns in the network are noticeably dominated by some academic fields like chemistry and life sciences, with relatively higher participation. These results showed an obvious distinction compared to the proportion of each discipline for all members of KOSEN. In other words, the postings of questions were not necessarily proportional to the KOSEN members in the field. A previous study showed the following proportion of all members: life and health sciences 23%, electricity and electronics 20%, machinery and materials 16%, and chemistry and chemical engineering 9% (Hwang, 2015). Thus, although approximately half of the 'What is?' questions in this study were related to chemistry, members in the fields of chemistry and chemical engineering numbered less than 10% of the total KOSEN members.

Moreover, the socio-gram was understood as a severe form of 'small-world' networking, linking completely all to one by an average of 2.336 steps (with a maximum of six steps), despite the fact that the network density was too low. An earlier study showed that the former dominant Korean social network service had the small world phenomenon of strangers being linked by a short chain of acquaintances; i.e. 4.3 steps (Kim, Park, & Jeon, 2006).

Also, the specific analysis by discipline showed there are meaningful differences in the interaction levels and patterns by discipline. In detail, regarding the form and quality of interactions, questioner-skewed and answered-skewed in this case, dispersed patterns were diverse according to the field of science. It was observed that the structure of the network differs depending on the discipline.

The most active field was chemistry, followed by life sciences. The social interactions in chemistry, electronics, physics, and health science were generated by a few posers while questioners and answerers in life and materials science showed nearly equal activity levels. It is interesting that there were some differences in participants' interactions according to the discipline, despite the facts that the attributes of each discipline belonging to science and technology are generally homogeneous. The results confirmed that some subject fields are more active in scientific collaboration (Bozdogan & Akbilgic, 2013).

Based on Zhu (2006)'s types of interactions, the overall network structures in the Q&A sites seem to be a type of interconnected web while the interaction patterns by some disciplines showed a star type of interactions where small numbers of members are central in the network. The disciplines with low participation such as materials science and electronics showed the star type of interactions where one or two members are central to the interactions. Thus, these results confirm that the network with low interactions was influenced considerably by a few leading posters.

By triggering message replies and sparking conversation, the active participants play a crucial role in sustaining online activities (Butler et al., 2002). For example, a high-profile leading member posted 117 times in one year in this study. Strong ties and energetic posters were often observed in posts related to personal interests or in an emotional community in several studies (Pfeil & Zaphiris, 2009; Baek & Kim, 2015).

Second, this study investigated how the contents in the Q&A site are related to information sharing activity. The results showed that contents such as manipulation and explanation for experiments are relatively more questioned and answered. It can be explained that rapid and deep responses can be obtained more readily stemming from sympathy from other participants when help is needed in an urgent situation, such as when conducting experiments. Thus, the interaction intensity relies on the content that the question requires.

Moreover, the aforementioned previous study confirmed that fields in which experiments were often conducted have more interactions with other members; many postings and interactions to exchange specific expertise were related to manipulations or explanations of experimental processes (Kim & Yoon, 2011). Among the questions in chemistry, experiments which are performed often accounted for the largest amount at 31%, while those related to the environment accounted for only 4% in that study.

5.2. Implications and Limitations

This study contributes to the understanding of interaction patterns in a professional online community focusing on Q&A activities. Although there were many studies on the interaction patterns of online professional communities, this study focused on the Q&A activities on a POC, which used an online platform for information seeking and sharing among professionals. Related to information sharing, these study results revealed that online participations in a Q&A site are not highly active, and the contents exchanged through the Q&As are urgent information needed for scientific research activities. It showed that the Q&A activities of a POC are not in the level of knowledge creation or scientific collaboration.

This study has provided an understanding of the interaction patterns and structures of the social networks of its members in detail. Thus, this study provides some practical implications to sustain a professional online community. Moreover, it is shown that factors such as the job positions of the participants, the characteristics of the scientific field, and the attributes of the contents category led to lively activity. Based on the results of this study, in order to be maintained successfully, online professional communities should consider the characteristics of various academic fields.

It is likely that good answers follow good questions. Likewise, the major determinant of interaction is the content of questions. Thus, rewards or incentives to posting questions could encourage participation online. Hung, Lai, and Chou (2015) suggest that different sets of underlying factors affect posters' and lurkers' behavioral intention formation in professional online communities. Posters were positively influenced by enjoyment in helping others in attitudes toward information sharing, whereas lurkers were positively influenced by reciprocity and technology adoption variables in attitudes toward information sharing by professionals.

However, this study has several limitations. Since the data of this study were based from a Korean professional online, it is limited in the generalization of the findings. Further study can be conducted to compare the interaction patterns in different types of professional communities. Also, the social network is only partly revealed given the time frame of only one year for data collection. Hence, it did not show evolutionary changes over a long period of time. Thus, if further study can undertake data collection for three or more years, it may attain more meaningful results. For example, for KOSEN there is a need to work out follow-up measures for stable interactions to evoke active participation by many scientists and engineers, as many fields of science have no balance of interactions between questioners and answerers, with all interaction swayed by a few key posters.

In further research on SNA in parallel with qualitative methodologies such as in-depth interviews with lively actors and even lurkers, POC managers and government personnel can establish specific action plans to improve the quality of interactions and the social networks of POCs.

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