

# Membership Fluidity and Knowledge Collaboration in Virtual Communities: A Multilateral Approach to Membership Fluidity

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In this era of knowledge economy, a variety of virtual communities are proliferating for the purpose of knowledge creation and utilization. Since the voluntary contributions of members are the essential source of knowledge, member turnover can have significant implications on the survival and success of virtual communities. However, there is a dearth of research on the effect of membership turnover and even the method of measurement for membership turnover is left unclear in virtual communities. In a traditional context, membership turnover is calculated as the ratio of the number of departing members to the average number of members for a given time period. In virtual communities, while the influx of newcomers can be clearly measured, the magnitude of departure is elusive since explicit withdrawals are seldom executed. In addition, there doesn't exist a common way to determine the average number of community members who return and contribute intermittently at will.

This study initially examines the limitations in applying the concept of traditional turnover to virtual communities, and proposes five membership fluidity measures based on a preliminary analysis of editing behaviors of 2,978 featured articles in English Wikipedia. Subsequently, this work investigates the relationships between three selected membership fluidity measures and group collaboration performance, reflecting a moderating effect dependent on work characteristic. We obtained the following results: First, membership turnover relates to collaboration efficiency in a right-shortened U-shaped manner, with a moderating effect from work characteristic; given the same turnover rate, the promotion likelihood for a more professional task is lower than that for a less professional task, and the likelihood difference diminishes as the turnover rate increases. Second, contribution period relates to collaboration efficiency in a left-shortened U-shaped manner, with a moderating effect from work characteristic; the marginal performance change per unit change of contribution period is greater for a less professional task. Third, the number of new participants per month relates to collaboration efficiency in a left-shortened reversed U-shaped manner, for which the moderating effect from work characteristic appears to be insignificant.

**주제어** : Virtual community, fluidity, turnover, member retention, knowledge collaboration

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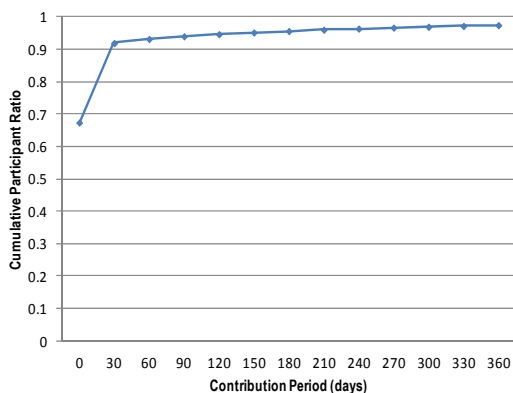
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## 1. Introduction

In this era of unprecedented globalization and virtualization, virtual communities are playing an increasingly important role in creating knowledge and software artifacts. Virtual communities offer a great deal of diversity, a crucial factor for solving difficult problems transcending temporal and geographical constraints, at little operational cost. They are also characterized by high membership turnover (Faraj et al., 2011; Ransbotham and Kane, 2011). Over half of the participants who take part in open source software communities post just once (Ducheneaut, 2005), and more than two thirds of newcomers to Usenet groups do not return after posting their first message (Arguello et al., 2006). Additionally, about 67% of the editors who participate in the development of featured articles found on English Wikipedia contribute only once, and about 92% of the editors revisit the same article for less than 30 days, as shown in Figure 1.



〈Figure 1〉 Cumulative Participant Ratio for Contribution Period

Traditionally, membership turnover has been widely regarded as detrimental to organizational performance (Glebbeck and Bax, 2004; Huselid, 1995; Ton and Huckman, 2008). Withdrawal of members can incur new member recruitment and training costs (Hom and Griffeth, 1995), loss of the unique knowledge and expertise of departing members (Carley, 1992), and impairment of organizational routines and social networks (Dess and Shaw, 2001). Hence, many studies have focused on enhancing the satisfaction level of employees to minimize external voluntary turnover (Tett and Meyer, 1993). In contrast, the negative effects of turnover in virtual communities may be mitigated by the aid of sophisticated collaborative technologies (Kane and Alavi, 2007; Ransbotham and Kane, 2011). Web 2.0 collaboration platforms are typically equipped with the capability to automatically store all activities and contributions made by participants so that remaining participants and newcomers can utilize the preserved knowledge resources as needed (Kane and Fichman, 2009; Wagner and Majchrzak, 2006). Furthermore, recruitment and training costs are not likely to be invested in virtual communities. Synthesizing all these differences, the overall turnover mechanism of virtual communities gains strong necessity to be investigated with regard to collaboration outcomes. In addition, it will be worthwhile to examine whether the relationship between turnover and collaboration outcomes is affected by work characteristics. Many studies revealed the effect of work characteristics on organizational performance in offline environments

(Li et al., 2009; Spreitzer et al., 1999). Since virtual communities for knowledge collaboration are often intended for a specific work, such as creating a variety of articles or software programs, work characteristics may exert a significant effect on the collaborative dynamics.

However, methods of measuring membership turnover in virtual communities are still unclear. In a traditional context, membership turnover is calculated as the ratio of the number of departing members to the average number of members for a time period (Kacmar et al., 2006; Shaw et al., 2005). In virtual environments, while the arrival of a newcomer can be easily detected, departure is difficult to confirm since explicit withdrawal procedures are seldom executed. In addition, there doesn't exist a common way to determine the average number of community members who contribute intermittently at will.

Therefore, our goal is to deal with the following research questions in virtual communities;

- How can membership turnover be properly gauged in virtual environments? Are there any alternative measures for membership turnover?
- How do these fluidity measures relate to collaboration outcomes?
- Will the relationship between the fluidity measures and collaboration outcomes be affected by work characteristics?

To find answers to the research questions, firstly, we examine the limitations in applying the concept of traditional membership turnover to virtual communities, and derive five measures for

membership fluidity of virtual communities. We select three measures among these five based on correlation analysis. Secondly, we investigate the relationships between the three fluidity measures and group collaboration performance, reflecting the moderating effect of work characteristic. Specifically, we analyze the collaborative behaviors of editors who have participated in developing 2,978 featured articles of the best quality in English Wikipedia.

Membership fluidity, giving rise to dynamic flows of knowledge resources, is a critical component of virtual communities (Faraj et al., 2011). This study illuminates the collaborative dynamics surrounding membership fluidity from several measuring angles to enhance group performance.

## **2. Theoretical Background and Membership Fluidity Measures**

### **2.1 Membership Turnover and Performance in Traditional Organizations**

Though the negative standpoint has been most prevalent, the relationship between membership turnover and performance in organizations can be viewed from three differing perspectives. In each perspective, the advantages and disadvantages of membership turnover were largely evaluated through the lenses of human capital theory, incurred operational costs, and more recently, social capital theory.

The first dominant perspective is that turnover is

negatively associated with organizational performance (Glebbeek and Bax, 2004; Ton and Huckman, 2008). Membership turnover has detrimental impacts on efficiency (Alexander et al., 1994), sales growth (Batt, 2002), productivity (Brown and Medoff, 1978), and safety (Shaw et al., 2005), for it incurs replacement costs required for recruiting and training new employees (Darmon 1990; Hom and Griffeth 1995), undermines existing working relations or social networks (Dess and Shaw, 2001; Leana and Van Buren, 1999), and constricts the knowledge base of organizations (Argote and Epple, 1990; Carley, 1992).

The second perspective points out that turnover may be beneficial to organizations in certain contexts. The remaining members could experience better working conditions without the most dissatisfied employees (Krackhardt and Porter, 1985). In addition, since knowledge management systems allow organizations to rake in and accumulate knowledge from diverse members, the value of individual members, from the viewpoint of the organization, substantially shrinks once their unique knowledge has been stored in a knowledge repository (Griffith et al., 2003). Further, it may be true that faster turnover rates, while eliciting and storing employee knowledge, yield greater performance achievement (Griffith et al., 2003).

The third perspective argues that a moderate level of turnover is best for organizational performance (Abelson and Baysinger, 1984; March, 1991), explaining that turnover can exert a positive impact to some extent. The knowledge and expertise of static organizations without any

turnover are likely to become outdated, obsolete, and rigid (Shaw et al., 2005). With the influx of new employees, possibly filling vacant positions of departing employees, new skills and knowledge can flow into the organization and foster the growth of the organization's knowledge base (Madsen et al., 2003). In addition, natural turnover may save costs invested in cautiously screening new hires by naturally preserving better employees and removing worse employees (Siebert and Zubanov, 2009). If organizations expend effort to lessen natural turnover, the entailed costs may exceed the costs from the negative effect of turnover (Glebbeek and Bax, 2004).

## **2.2 Work Characteristics and Group Performance**

Work characteristics can be roughly classified into three categories: job characteristics, cognitive or knowledge characteristics, and social characteristics. Studies on job characteristics describe the range and nature of tasks necessary for a specific job through the analysis of work procedures (Hackman and Oldham, 1976). Eventually, they identified five job characteristics—task autonomy, task variety, task identity, task significance, and feedback—and sought to design job characteristics in order to boost organizational members' motivation, satisfaction, and ultimately, their performance (Morgeson and Humphrey, 2008). Next, studies on cognitive or knowledge characteristics address the types of knowledge, skill, and ability required to conduct a task

(Morgeson and Humphrey, 2008). Cognitive or knowledge characteristics, such as job complexity, information processing, problem solving, skill variety, and specialization, are attracting critical attention with the explosive growth of complex knowledge work supported by ICT. In the third category, social characteristics center on the structural characteristics of a task as vital factors for work design reflecting social interactions and environments (Humphrey et al., 2007). Social characteristics, encompassing task interdependence, social support, interaction with other organizations, and feedback from others, are also receiving special interest with the increasing adoption of teams to accomplish complex tasks that are difficult to be completed separately.

Notable studies on the relationship between work characteristics and organizational performance suggested the following: Task autonomy enhances feelings of obligation and leads to effective group performance (Hackman and Oldham, 1976; Spreitzer et al., 1999). Higher task variety, task identity, and task significance result in more successful group performance (Li et al., 2009; Stewart, 2006), and task feedback helps to promote motivation, satisfaction, and performance of virtual teams (Geister et al., 2006). Some researchers focused on the different effects of group diversity according to work characteristic. Information diversity exerts a stronger positive effect on group performance with higher job complexity than with lower job complexity (Jehn et al., 1999; Pelled et al., 1999). In addition, information diversity and value diversity have a greater influence on group

performance with higher task interdependence than with lower task interdependence (Jehn et al., 1999; Williams and O'Reilly, 1998).

### **2.3 Membership Fluidity Measures of Virtual Communities**

As previously mentioned, there are two aspects to consider in applying the concept of traditional turnover to virtual communities; the difficulty of departure discrimination and estimation of the average number of working members for a given time period. Turnover rate of a virtual community has been defined as the percentage of members who made at least one edit in the previous quarter and didn't make any edits in the current quarter (Qin et al., 2014). It has also been calculated between  $t_1$  and  $t_2$  as the percentage of members who posted at least once by  $t_1$  but did not post in  $t_2$  (van der Vegt et al., 2009; Wang and Lantzy, 2011). These studies, however, didn't address the possibility of members returning after the current quarter or  $t_2$ , and used different time periods for counting leaving members and average number of working members. Another study (Ransbotham and Kane, 2011) indirectly inferred membership turnover by defining the concept of average experience as the ratio of the total number of prior edits to the number of total edits made by members for a given month and taking the inverse of the average experience. While this measure appropriately deals with the ambiguous aspects regarding turnover of virtual communities, its focus on edits rather than members makes it a

little challenging to conjecture how fast members actually come and leave. Additionally, this measure seems to gain full validity only when every participant consistently edits with uniform time intervals. However, the distribution of editing time intervals identified on Wikipedia by a preliminary analysis resembles a power distribution.

To derive a turnover formulation reflecting the aforementioned limitations, we conducted further analysis on the distribution of contribution period, which refers to the time period for which members revisit the same article for contribution. When a member's last edit, before the corresponding article is promoted to the featured article level, is tentatively regarded as the trigger for promotion, the contribution period tends to be much shorter than the article duration from article initiation to promotion to the featured article level. The ratio of article duration to average contribution period ranges from 2.7 to 3,192.3 with mean and median reaching 57.5 and 41.7, respectively, as shown in <Table 1>.

<Table 1> Distribution of the Ratio of Article Duration to Average Contribution Period

Mean	Median	Min.	Max.	Std. Dev.	Percentiles		
					25	50	75
57.519	41.696	2.716	3192.340	85.203	20.291	41.696	75.444

This result demonstrates that, though the departure of members can't be recognized on a real time basis, it can be guessed with considerable accuracy when observed for a sufficiently long

time. More specifically, considering that Wikipedia participants tend to contribute to an article for a very short time period relative to article duration and don't return for a long time, it seems reasonable to regard the last edit as withdrawal. <Figure 1> in the preceding section was drawn in this manner. On the other hand, we adopted an idea from previous studies to count active members who have made a contribution as working members (van der Vegt et al., 2009; Qin et al., 2014; Wang and Lantzy, 2011) and consider the number of those who made at least one edit during a time period as the number of members corresponding to that time period.

In contrast to stable traditional organizations, virtual communities are more fluid in that their boundaries, norms, members, artifacts, interactions, and foci continually change over time (Faraj et al., 2011). Among the varying elements of virtual communities, change in members is the most fundamental source of change in other elements. In particular, due to the low entry barrier of a virtual environment, ease of member entry is a significant factor affecting the general composition of members as well as member exit. Hence, the fluidity of members needs to be measured by inflow rate as well as turnover rate. In addition, it may be worthwhile to measure membership fluidity by adding both inflow and outflow of members to reflect the total change in members. In another respect, contribution period, which refers to the contribution time period between the first and the last contributions, may well be used as a fluidity measure without the necessity of

&lt;Table 2&gt; Definitions of Membership Fluidity Measures

Measure	Definition
1. Turnover Rate	(the number of participants who made their last contribution during a given time period / the number of participants who made at least one contribution during the given time period) * 100
2. Inflow Rate	(the number of participants who newly joined during a given time period / the number of participants who made at least one contribution during the given time period) * 100
3. In-Out-flow Rate	(the number of participants who made their first or last contribution during a given time period / the number of participants who made at least one contribution during the given time period) * 100
4. Contribution Period	the time period between the first and last contribution
5. Number of Newcomers per Month	the number of participants who newly joined during a given month

&lt;Table 3&gt; Correlations between Membership Fluidity Measures

	1	2	3	4	5
1. Turnover Rate	1				
2. Inflow Rate	.901	1			
3. In-Out-flow Rate	.896	.927	1		
4. Contribution Period	-.529	-.519	-.509	1	
5. Num. of Newcomers per Month	.198	.193	.196	-.267	1

computing the average number of members. Longer contribution periods imply lower membership fluidity. To prevent any ambiguity involved in calculating turnover rate, the number of new members, rather than that of leaving members, during a period of concern may be a useful measure. Based on this, the following five fluidity measures are defined in <Table 2>.

With the time unit of analysis unified to a month, correlations between the fluidity measures on Wikipedia are presented in <Table 3>. The correlations between turnover rate, inflow rate, and in-out-flow rate are all considerably high, as

shaded cells show, which seems to be mainly a result of the high percentage of one-time contributors. Due to the high correlations and typicality of turnover rate, turnover rate has been chosen as a focal variable for the three closely-correlated variables in this study.

### 3. Membership Fluidity and Collaboration Efficiency in Virtual Communities

#### 3.1 Membership Turnover

### 3.1.1. Membership Turnover and Collaboration Efficiency

While membership turnover in traditional organizations places stress on the loss of members, both the acquisition and loss of members have an almost equally balanced ambivalent meaning in virtual communities. Due to the short contribution period, the existence of many departing members implies the existence of many joining members. In short, high membership turnover in virtual communities indicates that members are replaced with high speed, indicating high membership fluidity. With this notion, we can examine the relationship between membership turnover and collaboration efficiency through the three lenses suggested in the previous literature: replacement and training costs, human capital theory, and social capital theory.

First, replacement and training costs are negligible in virtual communities. Recruitment of new members is generally dependent on spontaneous word of mouth (Kraut et al., 2010), and assimilation of new members into the community culture mostly requires only bulletin information regarding desired behaviors and observation of the behaviors of veteran members. Second, regarding human capital, since turnover empirically implies both influx and outflux of members in virtual communities, the impact of turnover on collaboration efficiency is ambiguous. Human capital, defined as the unique knowledge, skills, perspectives, and certifications of individuals (Becker, 1962), increases and decreases according to the movement of members. Considering that

human capital on a specific topic develops through a lengthy concentration on the given topic, rapid movement of members can be detrimental to the growth of human capital. Due to the nature of online platforms to automatically save all communications and posts generated by community members, the loss of human capital may be mitigated (Kane & Alavi, 2008; Griffith et al., 2003), and quick accumulation of new knowledge from new members may act positively on human capital. However, without sufficient devotion of time to learning the accumulated knowledge, enhancement of the quality of human capital is limited, and too much information may increase complexity. Furthermore, due to the importance of context (Szulanski, 2000), knowledge doesn't completely transfer into written form to the fullest extent. In other words, the community repository does not include all of the knowledge that members possess. Additionally, tacit knowledge may emerge only when a specific problem arises. Therefore, we are more supportive of the negative position with respect to the relationship between turnover and human capital.

Third, turnover may negatively influence social capital, since more social capital will be accumulated in longer-lasting relationships. Social capital is broadly defined as an asset embedded in the fabric of relationships (Leana and Van Buren, 1999), comprising cognitive, structural, and relational capital (Putnam, 1995). Cognitive capital refers to the resources that enable common interpretations and understanding of a collective group. Structural capital of a collective refers to



the density of connections or direct ties between individual members, whereas relational capital implies the affective nature of relationships formed in a group. Combination and exchange of knowledge is facilitated when structural, cognitive, and positive relational capitals exist (Nahapiet and Ghoshal, 1998). The withdrawal of individuals creates holes in a social network, reducing structural capital and damaging the efficiency and productivity of the organization (Shaw et al., 2005; van der Vegt et al., 2009). Analogously, a loss of participants in a virtual community may indicate that essential components of shared norms and visions are no longer available (Lazar and Preece, 2002), possibly with impaired cognitive capital, or that certain collaborative roles of the departing members are missing (Ransbotham and Kane, 2011). In particular, turnover of members who have interacted with many others for a considerable time inevitably disrupt the social network in a virtual community, eroding social capital. Although new members replace leaving members, social capital is not likely to be cultivated among fast moving members.

Overall, membership turnover impedes collaboration by impairing social capital. However, when many diverse members contribute to a certain level, the influence of social capital may diminish, and that of incoming human capital may increase. Diversity can dramatically accelerate well-framed tasks that require little coordination (Carr, 2007). At later stages of article creation, high turnover may not be so harmful and can be conducive to collaboration efficiency. Therefore,

we posit the following hypothesis.

H1-1: Membership turnover and collaboration efficiency have a curvilinear relationship that is negative initially but attenuated at higher levels of turnover.

### 3.1.2. Membership Turnover and Collaboration Efficiency with Work Characteristics

The complexity of organizational work has been constantly increasing, and more cognitive efforts are required to accomplish them. Naturally, the importance of flexible work environments, collaboration, and diversity of work groups is also growing (Oldham and Hackman, 2010). Wikipedia articles vary in the extent to which they refer to academic papers published in professional journals. Some articles refer to no academic papers while others consult more than one hundred academic papers. Articles with more professional topics linking to more academic papers are likely to take a longer time to become promoted to the featured article level. Work complexity of more academic articles is higher, and more information processing, problem solving, skill variety, and specialization is required to complete them. Some studies report that informational diversity influences group performance more positively with higher work complexity (Bantel and Jackson, 1989; Jackson et al., 2003; Jehn et al., 1999; Pelled et al., 1999). Thus, we presume:

H1-2: The relationship between membership

turnover and collaboration efficiency is moderated by the academic characteristics of the given work.

### **3.2 Member Retention**

#### **3.2.1. Member Retention and Collaboration Efficiency**

Member retention has been deemed crucial to the success and survival of a virtual community, since it is frequently the long-staying participants who undertake additional tasks (Butler et al., 2007) and offer benefits to others (Ackerman and Palen, 1996). With this implicit assumption, much research has sought to understand the factors inducing members to stay longer in virtual communities (Johnson, 2010; Joyce & Kraut, 2006; Farzan et al., 2011). More specifically, the necessity of member retention could be evaluated from the perspectives of human capital as well as social capital.

Regarding human capital, a longer time spent speculating on and exchanging knowledge of a specific topic leads to a deeper understanding gained by the participant regarding that topic. Hence, longer-staying participants will foster human capital. A drawback of long contribution duration that “old-timers” may prevent newcomers from staying longer has been noticed (Silva et al., 2008). When it comes to overall member retention, however, due to the early departure of a majority of participants, this side issue may be of lesser importance. Furthermore, in Wikipedia, the misconduct of old-timers sneering at or even

insulting newcomers could be mitigated through the community’s norms of seeking neutrality.

With respect to social capital, longer contribution period leads to more social capital, in turn exerting a positive impact on collaboration efficiency. Social capital increases in relationship networks over time, developing “transactive” memory (Wegner, 1987). It can benefit individuals by promoting the probability of promotion and career success (Burt, 1992; Seibert et al., 2001), and it benefits organizations by enhancing communication efficiency and employee trust (Leana and Van Buren, 1999). A stable group of participants can share experiences working together, develop effective rules and norms, and agree on a common vision for the community (Lazar and Preece, 2002; Ren et al., 2007). Social capital facilitates the exchange and combination of knowledge (Nahapiet and Ghoshal, 1998, Warkentin et al., 1997; Wasko and Faraj, 2005), promotes knowledge integration, and enhances the quality of group decision-making and performance in a virtual environment (Robert et al., 2008). In accordance with these studies, group performance research conducted on Wikipedia showed that higher pre-existing social capital in the user talk network of editors resulted in an article reaching the featured article level faster (Nemoto et al., 2011).

Hence, the following hypothesis is postulated.

H2-1: Member retention in a virtual community positively relates to collaboration efficiency.

### 3.2.2. Member Retention and Collaboration Efficiency with Work characteristics

In general, more difficult professional tasks take longer to learn. Previous research has found that the amount of time spent is positively related to the outcome of a problem-solving task requiring controlled processing, and this effect of time on task outcome increases with task difficulty (Goldhammer et al., 2014). Since knowledge of less professional topics can be obtained more easily, the effect of member retention on collaboration efficiency for this type of task is likely to be greater than for more professional tasks. So, we postulate:

H2-2: The relationship between member retention and collaboration efficiency is moderated by the academic characteristics of the given work.

## 3.3 Member Inflow

### 3.3.1 Member Inflow and Collaboration Efficiency

Members play essential roles in virtual communities as well as in offline organizations. Members contribute group information and knowledge, maintain norms and values, and perform administrative activities in virtual communities (Bateman et al., 2011; Butler et al., 2007). Therefore, the capability of a community to continuously attract and maintain new members is critical to its survival and success (Butler, 2001). Additionally, segregation from external perspectives

can result in bias, susceptibility to overconfidence in existent knowledge (Schultze and Leidner, 2002), and staleness of knowledge (Garcia et al., 2003; Kane and Alavi, 2007). Thus, influx of participants with new ideas, perspectives, and information is crucial to enhance the quality of knowledge of a community. Diversity of expertise and knowledge is positively related to group performance (March, 1991), with a stronger effect for more complex work demanding multiple perspectives or higher creativity (Ancona and Caldwell, 1992; Hoffman and Maier, 1961).

However, one thing to note is that new participants may not be aware of the norms and rules of the community and the historical trajectory of knowledge evolution. Moreover, virtual communities don't have any mechanisms for assessing an individual's capability or level of knowledge before the applicant participates in the community. Hence, though more editors may lead to the development of a broader knowledge base and the enhancement of output quality, exceeding an appropriate point, this increase may exert a negative effect with similarly increasing errors and incomplete information. In conclusion, too many newcomers during a unit time period may cause complexity, hindering collaboration efficiency rather than acting as diversity beneficial to a collaborative outcome. Therefore, we posit:

H3-1: Inflow rate of new participants relates in a curvilinear fashion to collaboration efficiency in a virtual community, promoting it to an optimal point and undermining it

thereafter.

### 3.3.2 Member Inflow and Collaboration Efficiency with Work characteristics

Virtual communities including Wikipedia and Open Source Software projects are characterized by the core-periphery structure of contribution in which there exist a few enthusiastic members and a majority of occasional participants (Crowston et al, 2006; Kane and Fichman, 2009; Kuk, 2006). The optimal size of the “core” may vary according to work characteristics, and the proportion of newcomers who possess sufficient knowledge to affect the quality of output may decrease with the difficulty of task. In addition, the diversity and the complexity effects from newcomers may differ depending on the professional orientation of work. So, the following hypothesis is proposed:

H3-2: The relationship between member inflow and collaboration efficiency is moderated by the academic characteristics of a work.

## 4. Research Methodology

### 4.1. Data Collection

The editing histories of 2,978 English Wikipedia articles were crawled from their initiation to promotion to the featured article level in June of 2012. Crawling was performed with a Java program through HTTP API from Wikipedia, and data were stored and analyzed with SQLite

professional and a Java program.

The editing history of an article shows information about each contributor and the time of each contribution, from which the membership fluidity measures can be calculated. Members who registered for Wikipedia are recognized with their username and ID in the editing history, whereas anonymous members are identified only with their IP address. It was assumed that a unique IP address represents a unique anonymous member. Contributions by automation programs such as ‘bots’ or ‘scripts,’ created for performing simple repetitive tasks like correction of typos, were excluded from the analysis. The number of participants who contributed to 2,978 featured articles amounted to 736,806 when permitting redundancy across different articles and 428,357 when counting only unique participants.

## 4.2 Analysis

### 4.2.1. Regression Model

To examine the relationship between membership fluidity and group collaboration efficiency, we adopted the Cox regression, which is a semi-parametric proportional hazards model. The hazard rate  $h_i(t)$  for the  $i$ -th case at time  $t$  is formulated as  $h_i(t) = h_0(t) e^{b_0 + b_1 x_{i1} + b_2 x_{i2} + \dots + b_p x_{ip}}$ , representing the likelihood for an event to occur at time  $t$  on the assumption that the event has not happened yet. The variable  $h_0(t)$  denotes a baseline hazard at time  $t$ , and  $P$  equals the number of covariates. In this study, hazard or

event corresponds to the promotion of an article to the featured article level. Cox regression does not presume any functional form of  $h_0(t)$ , which is a function of only time and not of any covariates. Instead, the covariates are assumed to exert a proportional effect on the baseline hazard. Therefore, it is possible to predict the relative likelihood change of promotion for one unit change of a focal variable, even without the knowledge of the exact form of a baseline hazard.

Four Cox regression models were built according to the analysis purpose of each model. The first block in each model was examined for the control variables, and the consecutive block for examining the effect of the focal variables or the interaction effect between variables. All variables were standardized in order to compare the relative magnitudes of their effects on collaboration efficiency. The “Forward Stepwise Likelihood Ratio” method for SPSS was employed at each block.

#### 4.2.2 Dependent Variable

In Cox regression, the time duration to a hazard or an event is used as a dependent variable. In the case of this study, article duration, the time spent from article initiation to promotion to the highest featured article level, was utilized as a dependent variable. In Wikipedia, article quality is represented by seven article quality grades, and the “featured article” level is the highest grade that article collaboration groups can pursue to promote their article. Article duration differs enormously among

article groups. Some article groups succeed in having their articles promoted to the featured article level within days, whereas others take as long as ten years. When analyzed with appropriate control variables, article duration can indicate the collaboration efficiency of an article group.

#### 4.2.3 Control Variables

Different articles will exhibit different values on the number of editors, the editing frequency, the ratio of registered editors, the ratio of editors who participate in task-oriented discussion, the level of completion difficulty, and the level of academic characteristics. The speed of quality improvement of an article may depend on these variables as well as the focal fluidity measures. Therefore, these variables have been included in the Cox regression models as control variables.

As more editors work on an article, a broader and more diverse knowledge base may be built-up, contributing to the enhancement of the quality of an article. At the same time, however, errors and conflicting information may occur. To reflect this ambivalent effect, the number of editors (NumOfEditors) was included. Mean inter-arrival time (MeanInterArrivalTime), in relation to overall contribution frequency, may likewise have an influence since higher editing frequency may lead to faster improvement of an article. In addition, a shorter inter-arrival time is likely to result in earlier nomination as a featured article because immediate feedback promotes more committed behavior (Csikszentmihalyi et al. 2005), with an

edit acting as a feedback to the work of the preceding editor.

Different article topics may vary in terms of difficulty in promoting the corresponding article to the featured article level. Thus, we assumed that the difficulty of article creation exists in descriptive, structural, and referential complexity, and is respectively operationalized with the length of an article in terms of bytes (ArtLength), the number of article sections (NumOfSections), and the number of references an article has (NumOfReferences). During preliminary analysis, article length appeared to be insignificant and was subsequently discarded. This implies that the number of sections and references can explain a large part of the work complexity represented by the article length. In general, registered editors are considered to make higher quality contributions than anonymous editors (Anthony et al., 2009; O'Reilly, 1989), and higher ratios of registered editors to total editors (RegEditorRatio) are expected to exert a positive effect on collaboration

efficiency. Virtual communities usually provide a public discussion tool to facilitate collaboration. In Wikipedia, ideas and opinions about article contents are shared and adjusted on the article talk page arranged for each article. As discussion enables the creation of organizational knowledge (Nonaka and Toyama 2005), the ratio of editors participating in article talk (DiscEditorRatio) is anticipated to boost collaboration efficiency. The more academic an article is, the more professional papers, such as those published at SCI, SSCI, A&HCI, or SCIE journals, it refers to. Completing a more academic article entails higher job complexity, requiring more information processing, problem solving, skill variety, and specialization. Hence, the number of referenced SCI, SSCI, A&HCI, or SCIE papers (LevelOfAcadChar) was incorporated as a control variable. Each journal list was downloaded in July 2013. We included the following control variables with their descriptive statistics and correlations in <Table 4> and <Table 5>, respectively:

<Table 4> Descriptive Statistics

Variable	Minimum	Maximum	Mean	Std. Dev.
1. MeanInterArrivalTime (days)	0.02	58.67	3.86	4.10
2. NumOfSections	0	43	14.02	6.11
3. NumOfReferences	0	456	67.45	50.82
4. RegEditorRatio (%)	25.05	100.00	70.41	18.81
5. DiscEditorRatio (%)	0.00	80.00	11.31	8.71
6. LevelOfAcadChar	0	117	1.66	5.84
7. TurnoverRate (%)	11.11	100.00	73.41	12.87
8. ContributionPeriod (days)	0.33	238.92	35.05	26.87
9. NumOfNEditorsMon	0.05	132.91	4.91	8.32

&lt;Table 5&gt; Variable Correlations

	1	2	3	4	5	6	7	8	9
1. MeanInterArrivalTime	1								
2. NumOfSections	-0.297	1							
3. NumOfRefereces	-0.244	0.590	1						
4. RegEditorRatio	0.292	-0.376	-0.304	1					
5. DiscEditorRatio	0.036	-0.264	-0.236	0.616	1				
6. LevelOfAcadChar	-0.016	0.120	0.093	-0.045	-0.190	1			
7. Turnover	-0.020	0.079	0.044	-0.395	-0.405	-0.001	1		
8. ContributionPeriod	0.337	-.0280	.0350	0.228	0.110	0.098	-0.529	1	
9. NumOfNEditorsMon	-0.342	0.218	0.236	-0.431	-0.172	-0.009	0.198	-0.267	1

- NumOfEditors: the number of total editors of an article
- MeanInterArrivalTime: the average time length between successive edits of an article
- NumOfSections: the number of sections an article has
- NumOfReferences: the number of references an article includes
- RegEditorRatio: the ratio of the number of registered editors to the number of total editors for an article
- DiscEditorRatio: the ratio of the number of editors who have participated in public discussion to the number of total editors for an article
- LevelOfAcadChar: the number of referenced papers published at SCI, SSCI, A&HCI, or SCIE journals

## 5. Results

<Table 6> shows the results of four Cox

regressions for different analysis purposes. All control variables were confirmed to be significant at a significance level of 0.001 in a two-tailed test across all models. In addition, all improvement chi-square statistics, indicating the effects of incorporating respective focal variables to the preceding model, proved to be significant, generally at a significance level of 0.001 with a few at 0.01. As we can see from the overall chi-square statistics, the hypothesis that all regression coefficients in the model are zero was rejected in all models. Since SPSS does not provide R square for Cox regression, we obtained pseudo R squares for each model with the “survival” package of open source R. The Kaplan-Meier curves drawn for all categorized covariates indicated that the proportionality assumption of Cox regression is fulfilled for each model (Park, 2007).

Several conclusions were drawn based on the interpretation of the above outcomes. First, shorter mean inter-arrival time (MeanInterArrivalTime) is likely to lead to faster promotion. This may be

partly due to the feedback effect, referring to the phenomenon of deeper flow or commitment induced by more immediate responses (Csikszentmihalyi et al., 2005), since subsequent edits can act as feedback for the preceding edit in Wikipedia. Second, articles with more sections (NumOfSections) or more references (NumOfReferences) require a longer time to be promoted to the featured article level. This result is in accordance with the anticipation that articles with higher structural and referential complexity are more difficult to complete. Third, a higher ratio of registered editors to total editors of an article group (RegEditorRatio) enables promotion in a shorter time. Since all activities of registered editors are recorded with their usernames, they are likely to be motivated by reputation or status (Constant et al., 1996; Lakhani and Wolf, 2005; Wasko and Faraj, 2005) and to contribute contents conforming to the community's value (Anthony et al., 2009; O'Reilly, 1989). Overall, the quantity and quality of contributions from registered editors are likely to be better than those of anonymous contributions (Anthony et al., 2009), and this seems to increase collaboration efficiency. Forth, a greater ratio of editors who participated in public discussion to total editors of an article group (DiscUserRatio) shortens the article duration needed for promotion. In Wikipedia, editors can express their opinions about the editing issues of an article, and compromise differing views on an article talk page arranged for each article. Speculating on others' ideas and perspectives through discussion helps to enhance individual

knowledge and facilitate the development of group cognitive capital as a whole (Nahapiet and Ghoshal, 1998; Wasko and Faraj, 2005). Therefore, public task-oriented discussions lead to a deeper and broader foundation of common understanding (Nonaka, 1994), exerting a positive effect on knowledge collaboration. Fifth, higher levels of academic characteristics of an article result in longer article duration.

### 5.1 Membership Turnover

Model 3 in <Table 6> demonstrates that membership turnover rate relates to collaboration efficiency in a curvilinear fashion. With the formula for the hazard rate  $h_i(t)$  introduced previously,  $h_i(t) = h_0(t) e^{b_0 + b_1 x_{i1} + b_2 x_{i2} + \dots + b_p x_{ip}}$  ( $h_0(t)$  is the baseline hazard at time  $t$ ,  $p$  is the number of independent variables), the log hazard ratio can be estimated as

$$\log \left( \frac{h_i(t)}{h_0(t)} \right) = b_0 + b_1 x_{i1} + b_2 x_{i2} + \dots + b_p x_{ip}.$$

When the control variables of Model 3 are assumed to be constant, the overall effect of turnover on the log hazard ratio reflecting the intensity of academic work characteristics is depicted in <Figure 2>. As in <Figure 2>, the log hazard ratio decreases over a long lower interval of actual turnover rate, then slightly increases over a short higher interval. Hence, hypothesis H1-1 proves to be supported.

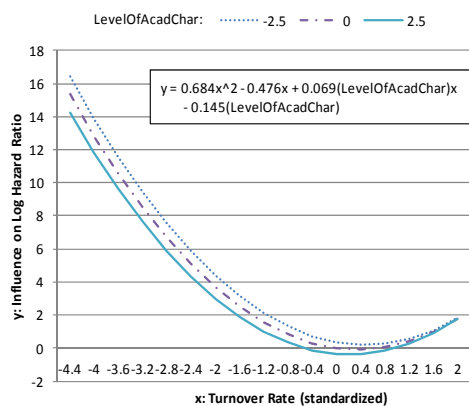


<Table 6> Relationships between Fluidity Measures and Collaboration Efficiency

Vars.	Model 1	Model 2	Model 3	Model 4
	B (Exp(B))	B (Exp(B))	B (Exp(B))	B (Exp(B))
MeanInterArrivalTime	-0.877*** (0.416)	-0.787*** (0.455)	-0.820*** (0.440)	-0.760*** (0.468)
NumOfSections	-0.138*** (0.872)	-0.136*** (0.873)	-0.123*** (0.885)	-0.108*** (0.898)
NumOfRefereces	-0.473*** (0.623)	-0.524*** (0.592)	-0.522*** (0.594)	-0.475*** (0.622)
RegEditorRatio	0.681*** (1.977)	0.878*** (2.405)	0.961*** (2.616)	1.051*** (2.861)
DiscEditorRatio	0.386*** (1.471)	0.373*** (1.452)	0.428*** (1.534)	0.462*** (1.587)
LevelOfAcadChar	-0.159*** (0.853)	-0.146*** (0.864)	-0.145*** (0.865)	-0.065** (0.937)
NumMonthNewEditors		0.582*** (1.790)	0.586*** (1.797)	0.356*** (1.428)
NumMonthNewEditors2		-0.425*** (0.654)	-0.407*** (0.665)	-0.182** (0.834)
TurnoverRate			-0.476*** (0.621)	
TurnoverRate2			0.684*** (1.982)	
TurnoverRate * LevelOfAcadChar			0.069** (1.072)	
ContributionPeriod				-1.220*** (0.295)
ContributionPeriod2				0.722*** (2.058)
ContributionPeriod2 * LevelOfAcadChar				-0.074*** (0.928)
-2LogLikelihood	39,422.729	39,270.207	39,170.175	38,416.137
Overall Chi-square	2,307.364***	2,518.319***	2,676.806***	3,714.049***
Improve. Chi-square	2,276.245***	152.522***	252.554***	1006.592***
R Square (%)	53.5	55.8	57.3	66.8

\*p<0.1, \*\*p<0.01, \*\*\*p<0.001 (two-tailed test), -2LogLikelihood for Null Model: 41,698.974

In addition, Model 3 in <Table 6> indicates the significant interaction effect of academic work characteristics and turnover rate on collaboration efficiency. While the interaction term TurnoverRate2\*LevelOfAcadChar degenerated during the automatic forward variable selection procedure of SPSS, the term TurnoverRate\*LevelOfAcadChar survived with a significance level of 0.01. This implies that the inflection point location of the curve depicting the relationship between turnover and collaboration efficiency varies according to the academic characteristic of



<Figure 2> Turnover Rate and Log Hazard Ratio with Work Characteristics

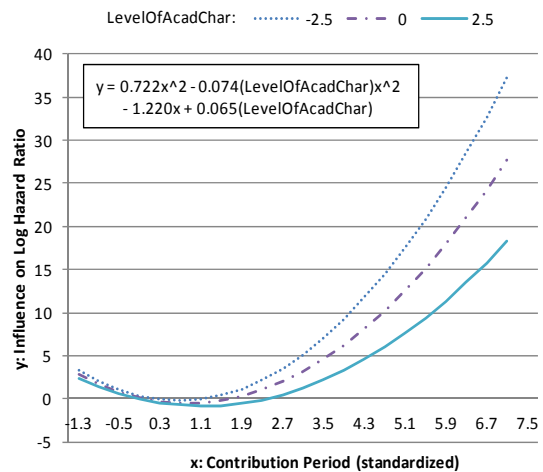
particular articles. In <Figure 2>, given the same turnover rate, the log hazard ratio for more academic work is lower than that for less academic work, and the difference between these two values diminishes as the turnover rate increases. Therefore, hypothesis H1-2 seems to be supported.

## 5.2 Member Retention

Model 4 in <Table 6> shows that member retention (ContributionPeriod) relates to collaboration efficiency in a curvilinear fashion. When the control variables of Model 4 are kept constant, the overall effect of member retention on the log hazard ratio reflecting the intensity of academic work characteristics is illustrated in <Figure 3>. As in <Figure 3>, the log hazard ratio slightly diminishes for a short lower interval of actual contribution period, then increases for a long higher interval. Therefore, hypothesis H2-1 can be regarded as partially supported.

In addition, Model 4 in <Table 6> demonstrates the significant interaction effect of academic work characteristics and member retention on collaboration efficiency. The interaction term  $\text{ContributionPeriod}^2 * \text{LevelOfAcadChar}$  survived the automatic forward variable selection procedure of SPSS. This means that the slope as well as the inflection point of the curve depicting the relationship between member retention and collaboration efficiency are affected by academic work characteristics. In <Figure 3>, given the same contribution period value, the log hazard ratio for more academic work is lower than that

for less academic work. The difference between these two values increases as the contribution period increases, with a higher marginal change in log hazard ratio for less academic work per unit change of contribution period. Therefore, hypothesis H2-2 proves to be supported.



<Figure 3> Contribution Period and Log Hazard Ratio with Work Characteristics

## 5.3 Member Inflow

Model 2, 3, and 4 in <Table 6> indicate that member inflow (NumMonthNewEditors) relates to collaboration efficiency in a curvilinear fashion. The log hazard ratio increases over a lower short interval of member inflow, then diminishes over a higher long interval of member inflow. Therefore, Model 2, 3, and 4 provide substantial support for hypothesis H3-1. On the other hand, the linear and quadratic interaction terms of member inflow ( $\text{NumMonthNewEditors} * \text{LevelOfAcadChar}$  and  $\text{NumMonthNewEditors}^2 * \text{LevelOfAcadChar}$ )

degenerated during the automatic forward variable selection procedure of SPSS. So, the interaction effect of member inflow and work characteristics turned out to be insignificant, and hypothesis H3-2 is not supported.

## 6. Discussion

### 6.1 Implications for Theory

Previous research on the effect of voluntary turnover in traditional organizations has largely focused only on the leaving members. In virtual environments, however, the abundance of outgoing members implies the existence of approximately as many incoming members due to overall short contribution period. Therefore, member turnover needs to be analyzed from a bilateral perspective—considering both outflux and influx of members—in virtual environments. Hence, we have used the term, membership fluidity, in this study. High correlations between turnover rate, inflow rate, and in-out-flow rate were presented and attributed primarily to the high ratio of one-time contributors in the current work, confirming the notion of membership fluidity.

Since high turnover indicates high fluidity in online settings, the consequences of turnover can be interpreted in conjunction with the change in social capital, of which accumulation is more likely to occur in a less fluid condition (Coleman, 1988). Loss in social capital from turnover relates to productivity in a curvilinear fashion in offline

settings; sharply negative as the loss moves from a low to mean level, but slightly positive (though not significant) when the loss increases beyond a mean level (Shaw et al., 2005). Additionally, in a virtual environment, especially in that of Wikipedia, the relationship between social capital loss and project performance has been reported as U-shaped with a significant mediation effect of turnover rate (Qin et al., 2014). Even though these studies do not offer plausible theoretical explanations about why performance improves as social capital loss increases beyond mean level, their results build substantial empirical ground for the present study. Since turnover and social capital loss are likely to move in the same direction (Shaw et al., 2005), it is reasonable that the relationship between turnover and performance resembles the relationship between social capital loss and performance.

It is necessary to take a look at the different outcomes varying according to a particular operationalization of membership turnover. When turnover is calculated through an edit-focused manner, the curve representing the turnover-performance relationship has been reported as reversed U-shaped (Ransbotham and Kane, 2011), but by a typical person-focused manner of this work, the curve appears to be U-shaped with a short right part. While the former argues that a moderate level of turnover is the best, the latter suggests that the lowest level of turnover leads to the best outcomes. These seemingly contradictory results may stem from the generally high turnover of virtual communities as well as the difference of

operationalization. In other words, depending on the range of turnover rate drawn from the data set, the resulting relationship curve may appear as a different shape.

Considering the critical effect of social capital on performance (Nemoto et al. 2011; Qin et al., 2014; Robert et al., 2008; Wasko and Faraj, 2005), the operationalization difficulty of turnover due to the vagueness of organizational boundaries, and the importance of attracting newcomers in virtual communities, a recommendable alternative may be approaching fluidity with member inflow and retention in a person-focused manner, as introduced in the current work.

## 6.2 Implications in Practice

Practitioners who manage virtual communities should note that only conventional turnover is not enough in virtual environments, and the effect of membership fluidity on the collaboration outcomes can be divergent depending on the particular operationalization of the concept. As aforementioned, turnover itself shows different results, depending on whether it is calculated in an edit-focused manner or a person-focused manner. Therefore, the formulas of membership fluidity measures deserve to be considered when the corresponding results are applied to virtual communities.

According to the person-focused turnover from this work, practitioners need to try to keep turnover rate low. Low membership turnover can be achieved through high member retention. A motivation mechanism providing psychological

benefits, such as reputation, knowledge self-efficacy, and pleasure from contributing knowledge to help others, should be implemented to retain members in virtual communities. Of course, cultivation of a supportive community culture, encouraging newcomers to freely express what they think, is essential for the effort of member retention.

From the perspective of the number of newcomers per unit period, a moderate level of inflow is recommended. Too many newcomers may cause coordination complexity rather than creative diversity. Intelligent platform capabilities guiding participants to make better contributions will be helpful, especially in high inflow state. For instance, when a revertive correction is detected, a platform feature to inform the member of the relevant history may cut down on unnecessary repetition and save time and effort. The possible loss of prior knowledge resulting from high turnover (Ransbotham and Kane, 2011) may also be mitigated by this sort of feature.

To sum up, virtual communities with low turnover (person-focused), high retention, and moderate inflow are likely to yield satisfactory outcomes in terms of collaborative efficiency. Besides, the magnitude of turnover and retention effects on the collaborative efficiency may vary according to the academic characteristics of work.

### Limitations and Suggestions for Future Research

Our results should be viewed with the following limitations and corresponding future research in mind. First, to enhance external validity, this research should be expanded to include Wikipedia

articles of different languages or other social media platforms. In other virtual communities, the actual ranges for variables and interactive dynamics among these variables may differ from those of English Wikipedia. It would be interesting to examine how well the results of this work can be applied to other virtual communities and to find specific contextual conditions that drive different consequences. Second, our research did not directly examine social capital loss as an intermediating factor between fluidity and collaboration performance. Building upon previous research on the relationship between social capital loss and performance with a moderating turnover, further research on the relationship between fluidity and collaboration performance incorporating social capital loss as a moderating factor may enable further clarification of collaborative dynamics. Third, though we recognized the necessity of general fluidity measures for virtual communities, our suggestions for membership fluidity measures are only the first step toward the exploration of virtual communities. It is hopeful that future research, building on our work, yields better fluidity measures for enhancing explanation power and predictability of community dynamics.

This work contributes to the understanding of membership fluidity in virtual environments. People can move freely with little obligation or with little temporal and geographical limitations in virtual space. With the advancement of internet platforms, traditional organizations also have been rapidly becoming more fluid. A deeper understanding of the fluid nature of virtual

communities will generate significant implications regarding how to handle the change of virtualization towards organizational success.

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## 국문요약

# 가상 커뮤니티의 멤버 유동성과 지식 협업: 멤버 유동성에 대한 다각적 접근\*

박현정\*\* · 신경식\*\*\*

오늘날의 지식기반경제에서 핵심적인 역할을 수행하고 있는 가상 커뮤니티의 성공을 위해 턴오버(turnover)는 매우 중요한 의미를 가지고 있다. 그런데, 이에 대한 연구는 많이 부족한 실정이다. 우선, 턴오버를 측정하는 방법부터가 명확하지 않다. 가상 커뮤니티에서 새로운 구성원의 유입은 비교적 확실하게 인지할 수 있지만, 탈퇴는 명시적으로 탈퇴 처리를 하는 사람들이 드물고 재방문 가능성이 상존하기 때문에 구별하기가 쉽지 않다. 그리고, 특정기간 동안 임의의 구성원이 해당 커뮤니티를 위해 활동하고 있는 진정한 구성원인지를 판단하는 방식이 분명하지 않아 전통적인 조직의 턴오버 공식을 그대로 적용하기 힘든 면이 있다.

본 연구에서는 이러한 한계점과 가상 커뮤니티 구성원의 행위 패턴을 고려하여, 일차적으로 턴오버를 포함한 가상 커뮤니티 구성원의 유동성(fluidity) 관련 척도들을 도출하고, 이를 토대로 유동성과 가상 협업 성과의 관계를 작업의 전문적인 특성을 반영하여 분석하였다. 요컨대, 대표적인 지식 협업 커뮤니티인 영어 위키피디아의 2,978개 피쳐드 아티클(featured article)에 대한 지식 협업 행위로부터 다음과 같은 결과를 얻었다. 첫째, 협업 효율성에 대한 턴오버의 관계는 오른쪽 부분이 짧은 U자 형태를 보이며, 똑같은 턴오버율에 대해 보다 학문적인 아티클을 완성하는 것이 더 오래 걸리고, 이 차이는 턴오버율이 증가함에 따라 감소한다. 둘째, 협업효율성에 대한 재방문기간의 관계는 왼쪽 부분이 짧은 U자 형태의 관계를 가지며, 전문적이지 않은 작업일수록 재방문기간의 일단위 변화에 대한 협업 효율성의 변화가 크다. 그리고, 똑같은 재방문기간에 대해 보다 학문적인 아티클을 완성하는 것이 더 오래

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결리며, 이 차이는 재방문기간이 평균이상으로 증가함에 따라 더욱 커진다. 셋째, 협업효율성에 대한 월(month)별 유입 신규 구성원 수의 관계는 왼쪽 부분이 짧은 역 U자 관계를 가지며, 이 관계에 대한 작업 특성의 영향은 유의하지 않은 것으로 보인다.

**주제어** : 지식 협업, 가상 커뮤니티, 유동성, 턴오버, 구성원 유지

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