Peer Production of Knowledge in Online Social Q&A Communities at Startup Stage

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PEER PRODUCTION OF KNOWLEDGE IN ONLINE SOCIAL Q&A COMMUNITIES AT STARTUP STAGE

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I dedicate this dissertation to my beloved father, Hongkui Fu, and my mother, Zhenfang Hu, and my grandparents Yufeng Zhang and Zhongyu Fu.

Thank you for everything.
I hope I make you proud.

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ABSTRACT

As one of the most significant and visible examples of collective intelligence, online peer production communities, such as Wikipedia and Stack Overflow, have become critical to the Web’s knowledge infrastructure. The popularity of these communities has led to a growing body of literature regarding issues of how to encourage commitments and contributions, regulate members’ behavior, or control the quality of community outputs. However, in reality many peer production communities didn’t survive until that stage they need to deal with the above challenges—they never really get off the ground. To build successful online peer production communities, it is essential to have a good understanding of how online peer production communities are self-developed to survive the initial growing pains at startup stage, and how new communities failed, especially comparing to those successful ones.

This study employed a mixed methods case study design with content analysis, social network analysis, and semi-structured interviews to examine differences between one successful and one unsuccessful online social Q&A community in the startup stage on Stack Exchange. In particular, the study examined and contrasted the two communities on how they defined their communities’ objectives and scopes; how they recruited, selected, and retained their community members; how they motivated members’ contribution, decided the community structures, and maintained the quality of community outputs.

The findings indicated that compared to the failed community Q&A community, the successful Q&A community devoted more efforts to activities of quality assurance, user management, tool development, promotion, and communication between members. It also set clear rules regarding community scope management and user moderation, as well as documented instructions to implement those rules. Besides content creators and moderators, the successful Q&A community
had unique user groups who were responsible for quality control, meta-content, and other community supporting work. The successful community also engaged in developing tools for question answering, content editing, searching and browsing, computation, graphic design, program, communication, moderation, and user education. The user network of the successful community was also connected and expanded largely by high-profile users such as moderators and high-reputation content contributors. Implications of this study are twofold. First, it could advance our theoretical understanding of the underlying mechanisms of successful peer production systems (especially theoretical claims of early stage community ecology and developing strategies), for example in mixed scope setting, user selection and recruitment, motivating contributions, etc. This study may also provide practical guidelines to designers of existing peer production communities and those who want to start a new one regarding policy, reputation, incentive system design as well as how socio-technical features could facilitate useful community building activities such as quality assurance, meta-content work, copy-editing, communication, user education, moderation, etc.
CHAPTER 1
INTRODUCTION

This dissertation presents a research study titled Peer Production in Online Social Q&A Communities at Startup Stage. As the name suggests, it examines difference in community building activities and strategies, as well as user interaction patterns of two social Q&A communities—one failed and one succeeded. This introductory chapter begins with an overview of the research purpose, a statement of the problem being considered, and the significance of the research. It then presents the research questions explored and the theoretical framework and approach applied in this study. Chapter 2 presents a thorough literature review of relevant research; Chapter 3 presents the details of the method and research procedures; Chapter 4 presents a detailed review of the study findings; and Chapter 5 discusses and synthesizes these findings, answers the research question, and considers in detail the implications of this research.

1.1. Problem Statement

1.1.1. Online Peer Production Communities

Peer production is one of the most significant and visible examples of collective intelligence that emerged from Internet-mediated social practice. Benkler, Shaw, and Hill (2013) defined peer production as a form of open creation and sharing performed by groups online that: (1) sets and executes goals in a decentralized manner; (2) harnesses a diverse range of participant motivations, particularly non-monetary motivations; and (3) separates governance and management relations from exclusive forms of property and relational contracts. Peer production includes many of the largest and most important collaborative communities on the Internet, like Wikipedia provide free reference resources with quick access; recommender systems like Amazon leverage users' ratings of consumer products to enable personalized recommendations;
Q&A sites like Yahoo! Answers and Stack Overflow form knowledge economies, where users spend points to ask or boost the priority of questions and earn them for answering. These communities have created some of the most powerful publicly maintained resources and services of modern life, and enabled new forms of communities to thrive around them. Participants in online peer production communities join and contribute valuable resources without the hierarchical bureaucracies or strong leadership structures common to state agencies or firms, and in the absence of clear financial incentives or rewards. As a result, foundational research on peer production was focused on (1) documenting and explaining the organization and governance of peer production communities, (2) understanding the motivation of contributors to peer production, and (3) establishing and evaluating the quality of peer production’s products (Benkler et al., 2013). However, studies comparing across different online peer production communities have remained challenging and rare. The most in-depth comparative study is (Schweik & English, 2012), who build on (Ostrom, 1990)’s work to compare characteristics of FLOSS projects’ organization, resources, governance, and context, using the FLOSSmole dataset of SourceForge projects.

1.1.2. Community Survival

Although some communities like Wikipedia have flourished, not all are successful, as numerous wikis, open source projects, and online discussion forums languish in a perpetual state of inactivity due to the lack of participation. Hunt and Johnson (2002) found that the distribution of download activity across open source projects hosted on Sourceforge followed a Pareto distribution, suggesting that only a few projects have substantial levels of activity, while most other projects are low-interest or dormant. More recent studies of Sourceforge-hosted projects show similar results (Schweik & English, 2012; Wiggins & Crowston, 2010), with well over half
of projects being classified as “tragedies” (abandoned projects). Arazy and Croitoru (2010) examined activity levels and patterns in over 33,000 corporate wikis within IBM, and marked over 90% as “not very sustainable”. Other communities, although they are able to elicit user participation, still suffer from excessive spamming, in-fighting, low-quality contributions, and other unwanted and non-constructive forms of participation. In response, researchers from various disciplines are searching for the conditions that make online communities successful or unsuccessful. The result of this effort is in an extensive body of literature that proposes design principles and guidelines derived from different sociology, psychology, management and economy concepts and theories, and a limited number of empirical studies. Kollock (1996)’s design principles for online communities concluded that the most salient design principles are the incorporation of identity persistence (i.e., ability to recognize members by names), group boundaries (i.e., ability to differentiate members), and permeated control (i.e., ability to allow group members to monitor and sanction members’ behaviors). Wasko and Teigland (2004)’s research agenda are built from theories on social dilemmas, cooperation, public commons, and collective action; they suggested participation in online social networks was dependent upon the attributes of the individuals in the collective, the relational structure of social ties between individuals in the collective, the norms of behavior of the collective, the affective factors of the collective, and the development of sanctions for noncompliance with network norms. Preece (2000) articulated participatory design, sociability and usability concepts and recommends applying these concepts in building communities. More recently, researchers have started empirically testing independent conditions that can indicate the success of these communities. Failed attempts to build online communities seldom attract scholarly attention. Two studies capturing these failures are Kittur and Kraut (2010) who used a dataset of 7,000 peer production
wikis from the hosting firm Wikia, and Shaw and Hill (2014) who used an updated version of this dataset. Others have tried to look across wikis by considering variation in sub-organizations within Wikipedia (Wang, Chen, Ren, & Riedl, 2012; Zhu, Kraut, Wang, & Kittur, 2011).

1.1.3. The Evolution of Online Communities

While online communities evolve in stages, activities and needs of members could change in each stage of the online community evolution. Thus community development requires different tools, features, mechanisms, technologies, and management activities at different stages. Wenger, McDermott, & Snyder (2002) made a first attempt to sketch the evolution of online communities by identifying five stages of community development, including defining, coalescing, maturing, stewardship, and transformation of the community, and concluded the key issues a community may encounter in each development stage. Andrews (2002) suggested three stages: starting the online community, encouraging early online interaction, and moving to a self-sustained interactive environment. Based on Wenger et al. (2002) and Andrews (2002), Iriberri and Leroy (2009) labeled five stages of the online community life cycle as inception, when an online community emerges because of people’s needs for information, support, recreation, or relationship; creation, when the initial group of members can begin to interact and spread the word for other members to join; growth, when the community culture, identity, and leadership structure for the community are developed; maturity, when a more explicit and formal organization (regulations, rewards, subgroups, etc.) is formed; and death. Each stage presents distinct requirements and challenges, thus stressing specific success factors at a certain stage of evolution will be more important. For example, success factors such as a clear scope, purpose, focus, and a code of conduct in this stage are extremely important at community creation stage. Matching features with each community life cycle stage may more efficiently lead to success,
and technology and mechanisms that support and ensure success of online communities should evolve to match their growth and evolution (Iriberri & Leroy, 2009). Jullien, Crowston, and Ortega (2015) suggested that three phases can be identified in the life of a collective action project: the initial phase, where the returns on investment are less than the investment but increasing; the diffusion phase, where it is increasingly rewarding to participate in the collective action; and the mature phase, when the returns on contributions are decreasing and thus fewer contributors are needed. However, those models are generally not substantiated with specific real-life examples.

1.2. Research Purpose and Significance

The purpose of this study is to understand the difference in successful and unsuccessful online social Q&A communities in the startup stages of their lifecycles. The significance of this study lies in three aspects. Firstly, online peer production communities, which enable loosely connected people to work together to produce shared services and resources termed as artifacts of lasting value (Cosley, Frankowski, Terveen, & Riedl, 2006), have become major information or knowledge sources in people’ daily lives. Besides the examples of Amazon, Wikipedia, and social Q&A sites, which serve as knowledge bases, the last few years have also seen the phenomenon of online peer production communities becoming key forces driving the development of offline societies themselves. For example, online support groups like PatientsLikeMe\textsuperscript{1} and Inclusive Planet\textsuperscript{2} are increasingly being used to complement offline social support for people with health ailments or disabilities. There are also several examples where collection and exchanges of information online has improved crises responses (Palen et al.,

\textsuperscript{1} https://www.patientslikeme.com/
\textsuperscript{2} http://inclusiveplanet.com/
2010). The Ushahidi project has enabled crowd-sourcing and peer production to be used for social activism, public accountability, and crises responses, including the 2007-2008 elections in Kenya and earthquakes in Haiti and New Zealand (Okolloh, 2009). Online communities not only generate and provide knowledge resources with low cost access, but also have tremendous potential to complement both online and offline movement of societies. This budding need should be tapped through contemporary research and efforts devoted to improving existing peer production communities and designing better ones.

Although online peer production communities are of great value, actually building and maintaining a successful one is difficult. Motivating individuals to participate in constructive ways is a big issue; the free rider problem and the tragedy of the commons dilemma suggest that while many people stand to benefit from successful online communities, they may not be quite as willing to contribute. Also, since those who contribute are not necessarily experts in the relevant subject area(s), quality control can be another major concern. However, very little effort has been made to document the online peer production community development processes and provide guidelines to introduce success factors and design choices in an integrated and orderly way.

Studying user behavior in a startup stage community is of great significance because of the uniqueness of this stage. In the startup stage a community has more uncertainty, both in the community structure and membership, as well as less value, than it will after reaches steady stage. The scope of the community, in terms of the breadth of topics to cover, the kind of people it tries to attract as members, the activities it supports, and the purpose of the community as well as the norms and governance need to achieve that purpose, may still under a rough agreement among its early-stage members. Also since the resource and interaction opportunities are limited, the community could experience difficulty in attracting potential members; a higher possibility
of member loss could also be expected since the switching costs of current members are much less. Thus, understanding community members’ information needs and interactions at community’s startup stage could help community designers make sound design choices, survive the initial growing pains, ensure an optimal development process and maximum success.

Finally, cross-community studies in the area of peer production and failed attempts to build online peer production communities remain untouched. The current volume of online peer production communities research is vast but findings related to comparison between community success and failure are isolated. Online peer production community designers face a myriad of design strategies and features with little guidance on how to integrate these when building online community in different community development stages. Empirical studies about how new communities failed, especially comparing to those successful ones, can facilitate development and maximize success of online peer production communities. The differences in community design process and building strategies between successful and unsuccessful communities and how sociability-support and technological components are selected and incorporated in both could shed light on how the community building process to ensure an optimal development process and maximum success.

1.3. Research Questions

The research questions this study is trying to answer include:

1. What are some of the activities in social Q&A communities at the startup stage? What are their objects?

1.1. Who are the subjects of those activities?

1.2. What are the motivations for engaging in these activities?

1.3. What are some of the norms and rules regulating these activities?
1.4. What is the division of labor within these activities?

1.5. What are some of the tools used in these activities?

1.6. What are some of the contradictions within and between these activities and how these contradictions have been solved?

1.7. What are some of the skills needed to participate in the community?

2. How does Stack Exchange define the success of a Q&A community?

2.1. What criteria are used by Stack Exchange to evaluate if a Q&A community has succeeded through each stage? Do the criteria shape and if so, how do they shape the community dynamics at the startup stage?

2.2. What do members consider as indicators to assess how successful a Q&A community is?

2.3. What do members consider as criteria and/or measures of high quality questions and answers?
CHAPTER 2

LITERATURE REVIEW

This chapter reviews the lifecycle of online communities, defining success in online peer production communities, and factors that may affect online communities. This is followed by a review of community activities at community creation stage and community growth stage. This chapter continues with an extended review of the Activity Theory and Collective Effort Model.

2.1. Online Peer Production Communities

Online peer production communities are those communities let loosely connected people work together to produce shared services and resources that are useful to more than those who created them. Such communities have been in existence as offline, real life communities for centuries, but the advent of the Internet in the last two decades has taken them to a new level. The Internet has abolished geographical boundaries and has enabled people from different parts of the world to contribute to, maintain and consume a shared resource with relatively little effort and cost. Online peer production communities have created some of the most powerful publicly maintained resources and services of modern life, and enabled new forms of communities to thrive around them. For example, online community-based encyclopedias like Wikipedia provide free reference resources with fast access; recommender systems like Amazon leverage users’ ratings of consumer products to enable personalized recommendations; and Q&A sites like Yahoo! Answers and Stack Overflow form knowledge economies, where users spend points to ask or boost the priority of questions and earn them for answering. Besides the examples of Amazon, Wikipedia, and social Q&A sites, which serve as knowledge bases, the last few years have also seen the phenomenon of online peer production giving rise to a new class of applications and being a key force driving the development of offline societies.
themselves. Peer production communities not only generate and provide knowledge resources with a low cost of entry, but also have tremendous potential to complement both online and offline lives of societies. Many efforts have been devoted to improving existing peer production communities and designing better ones. Topics covered by current literature include, but are not limited to: recruiting and retaining community members (Kraut, Burke, Riedl, & Resnick, 2012), encouraging contribution to the community (Lakhani & Wolf, 2005; Ling et al., 2005; Nov, 2007; Oreg & Nov, 2008; Wasko & Faraj, 2005), community governance (Forte & Bruckman, 2008; Forte, Larco, & Bruckman, 2009; Kriplean, Beschastnikh, McDonald, & Golder, 2007; Viégas, Wattenberg, & McKeon, 2007), work coordination (Kittur & Kraut, 2010; Kittur, Suh, Pendleton, & Chi, 2007; Stvilia, Twidale, Smith, & Gasser, 2008; Viegas, Wattenberg, Kriss, & Van Ham, 2007), expert locating (Bouguesa, Dumoulin, & Wang, 2008; Jurczyk & Agichtein, 2007), task rotating (Cosley, Frankowski, Terveen, & Riedl, 2006, 2007), and quality control (Bryant, Forte, & Bruckman, 2005; Cosley, Frankowski, Kiesler, Terveen, & Riedl, 2005; Lerman & Galstyan, 2008; Stvilia et al., 2008). However, current literature hasn’t fully addressed the community survival problem, especially those failed cases. Two studies capturing such failures are Kittur and Kraut (2010) who used a dataset of 7,000 peer production wikis from the hosting firm Wikia, and Shaw and Hill (2014) who used an updated version of this dataset with ten times as many wikis. Others have tried to look across wikis by considering variation in sub-organizations within Wikipedia (L. S. Wang et al., 2012; Zhu et al., 2011). Cross-community study is also very rare. One difficulty with comparative work across communities, in general, is designing research capable of supporting inferences into the causes of community success and failure. The most in-depth comparative study is Schweik and English (2012)’s, who build on the
work of Ostrom (1990) to compare characteristics of FLOSS projects’ organization, resources, governance, and context, using the FLOSSmole dataset of SourceForge projects.

2.2. Life Cycle of Online Communities

Online communities go through different stages, and each stage may present distinct characteristics. In an online community, the needs of users and management evolve along with the life cycle stages of the community, and community building efforts must take into consideration the needs of members and of the whole community in each stage (Andrews, 2002; Kling & Courtright, 2003; Malhotra, Gosain, & Hars, 1997). Malhotra et al. (1997) illustrated four stages in community design and used an online community of college football fans as example. They described the inception, beginning of user involvement, interactivity, and growth and experimentation activities of this community over a two-year period. The authors concluded to motivate contribution, features in the community must evolve according to members’ needs in each stage. Wenger et al. (2002) specified five stages in building online communities: potential, coalescing, maturing, stewardship, and transformation, each with a different domain, community, and practice issue. For example, the key domain, community, and practice issues at potential stage is defining the scope of interest to community members, discovering groups that engaged in the topic, and identifying common knowledge needs. Iriberri and Leroy (2009) did a comprehensive review of community life cycle models and proposed a five-stage model based on previous research, including inception, creation, growth, maturity, and death. They also argued that matching social and technological design with each community life cycle stage could be more efficient in leading to the community success. For example, a clear scope, purpose, focus, and a code of conduct are the first priority at community creation stage. Jullien et al. (2015) evaluated user efforts and participation in Wikipedia projects at different phases in the
project lifecycle. They suggested that three phases can be identified in the life of a collective action project: the initial phase, where the returns on investment are less than the investment but increasing; the diffusion phase, where it is increasingly rewarding to participate in the collective action; and the mature phase, when the returns on contributions are decreasing and thus fewer contributors are needed. They proved main Wikipedia projects were less efficient that smaller ones but didn’t further explore the determinants of project success in each phase.

2.3. Defining Success in Online Peer Production Communities

The majority of literature exploring definitions of success in online peer production communities focus on Open Source Software (OSS). This is partly because defining success is a topic that has already received a great deal of attention in traditional software engineering literature. Defining OSS success is complicated because of its ongoing, evolutionary nature; attempts to generate new metrics for OSS success have generally embraced a multi-dimensional conceptualization of success. They also tend to be informed by a combination of theory and multiple empirical data sources. English and Schweik (2007) produced a six-part classification, based on phone interviews with OSS developers, manual coding of a sample of OSS projects from SourceForge.net, and theoretical insights from Hardin’s “Tragedy of the Commons”. In this system, OSS projects can be successful, abandoned, or indeterminate at two key stages in their life cycle, Initiation and Growth. A successful initiation stage is defined as OSS developers achieving a first release, and a successful growth stage is defined as achieving three subsequent releases. They operationalized these definitions and tested them on 110,933 SourceForge projects, with low error rates. Wiggins and Crowston (2010) validated a refined version with another SourceForge data set, also with good results. Of 117,733 projects, they classified 31% as abandoned at the Initiation stage, 28% as abandoned at the Growth stage, and 14% as successful.
at both the Initiation and Growth stages. Crowston, Howison, and Annabi (2006) developed a set of 18 measures of OSS success, organized into four system process phases: creation and maintenance, quality, use, and consequences. These measures were based on DeLone and McLean (1992)’s process model for information systems, a literature review of success measures in OSS research, and a survey of OSS developers on SlashDot.org. They validated their model by operationalizing three of the 18 measures number of developers, bug-fixing time, and popularity and testing them on a sample of 120 SourceForge projects. The resulting correlations between measures suggested high convergent validity.

Little work has focused on success definitions in other domains of online peer production. As with OSS, many of these projects have no clear endpoint and place more focus on improving processes rather than measuring outcomes. For example, the purpose of Wikipedia as stated by Jimmy Wales, to give every person in the world free access to the sum of human knowledge, is sufficiently ambitious that it may never be reached, so most contributors view the project as a work-in-progress, albeit an active and highly promising one.

### 2.4. Success Factors of Online Communities

Suggestions of building successful online communities from various disciplines range from theoretical frameworks to design strategies and principles. Kim (2000) concluded nine design strategies and three design principles to increase the chances of success, including giving the community a purpose, encouraging etiquette, and integrating rituals. Cothrel and Williams (1999) proposed seven principles for success based on an extensive study of fifteen successful business online communities. They concluded the importance of three strategies: focusing on the needs of users, providing support for individual roles of members--such as moderators or experts--within the community, and facilitating the organizations of online and offline activities.
or events. Preece (2000) and Tedjmulia, Dean, Olsen, and Albrecht (2005) developed frameworks incorporating sociability-support and usable components in online community to ensure the success: sociability-support components include clear purpose, protocols, and codes of behavior; usability components include features and tools with which users can find information or navigate through the online community. Tedjmulia et al. (2005) also encouraged the incorporation of extrinsic reinforcements such as gifts, social recognition, and feedback to motivate online community members to contribute actively to the community. Blanchard and Markus (2004) applied theories of sense of community and emphasized the importance of having facilitators to encourage discussions and reward members for their contributions, and ensuring member’s legitimacy and persistent identity. Similarly, Ling et al. (2005) highlighted the need to encourage contributions by explicitly acknowledging members’ uniqueness of opinions.

Leimeister, Sidiras, and Krcmar (2004) summarized 30 different success factors based on previous research and ranked them according to importance from the perspective of participants and operators. They found that participants and operators valued first the ability of the online community to handle member data sensitively and the stability of the online community website. Leimeister, Ebner, and Krcmar (2005) empirically tested the impact on success of factors such as exposing the identity of managers and content providers, clearly establishing their goals for the online community, making up-to-date and expert-generated content available, making members’ profiles available for other members, and providing varying levels of anonymity. They found that these components build trust among members and motivate continued membership.

Others are testing many other components such as rewards for contributions, assignment of administrative roles to members, acknowledgment of members’ longevity, organization of online and offline public events, posting of member’s pictures and profiles, among others. integrated the
success factors into the information systems life cycle model (inception, creation, growth, maturity) for different types and genres of online communities, and suggested some factors are more important than others depending on the life stage or type of online communities.

2.5. Community Activities at Community Creation Stage

2.5.1. Define Scope

The scope of a community strongly influences the breadth of topics it covers, the kind of audience it tries to attract as members, the activities it supports, the purpose it serves, and the type of content it is relevant. In most online communities, people join the communities based on their shared interests in a particular topic, domain, or common goal. Defining the scope of a community is a major design decision to make when starting a community, and a clear articulated scope could help the potential users evaluate if they fit the community well and differentiate the community from its competitors (Ren, Kraut, Kiesler, & Resnick, 2012). A mixed-topic scope is expected to reduce the value of a community to its members since people are attracted to the community to the extent that they identify with the domain, scope, or causes on which the community is based, and mixing topics may triple the amount of useful information so potential members would discover that part of the content is uninteresting. Even when the scope is not mixed, ambiguity of the scope may also lower the shared value of the community since people interact with others who have different interpretation of what the community is about. Without a distinguished scope, a community might fail because many established communities have relevant content base to serve the potential members it targets. Especially for a newly created community that directly competes with mature communities on the same topic for a shared pool of members, the ambiguity of the scope might increase the switching cost of its
potential members of leaving other communities and getting start with the new one (Ren et al., 2012).

Although there are a few theoretical claims of community scope, very few empirical studies have investigated this issue. Wenger et al. (2002) recommended specifying clearly the community’s area of interest to its members. Maloney-Krichmar and Preece (2005) also found evidence of the importance of having a clear community scope with purpose in an online community of support for patients undergoing treatment for a knee condition. Wang, Butler, and Ren (2013) and (Zhu, Kraut, & Kittur, 2014) examined the impact of membership overlap on community activity. Wang et al. (2013) argued that membership overlap caused competition among communities for member time and attention that reduced the chance their opportunities for growth. (Zhu et al., 2014) built on Wang et al.’s work, finding that moderate levels of membership overlap between communities may bring benefits that outweigh the negatives, such as knowledge transfer and new member recruitment. The closest prior research is Zhu (2015)’s work about the effects of topic overlap on community success. Zhu (2015) reported a curvilinear relationship exists for a given community between its topic overlap with other communities and its activity level: high levels of topic and low topic overlap both led to low activity levels. However, Zhu (2015) didn’t completely explained the effect of community scope on the survival of online peer production communities--especially within a community--how the number of topics and ambiguity of community scope will influence the community success. As Resnick, Konstan, Chen, and Kraut (2012) suggested, some ambiguity about the eventual scope of the community may be natural and sometimes beneficial. The activity of negotiating the scope, especially through explicit meta-discussion about it, can lead the community members feel ownership of the community thus commit to it. However, these theoretical arguments haven’t been tested by empirical evidence.
2.5.2. Enforce Scope

The extent to which a community enforces its scope and deals with off-topic discussions will influence who joins the community and who stays. Off-topic posts out of the scope may be especially off-putting to newcomers whose initial expectations are likely to be violated. However, on the other hand, off-topic discussion provides opportunities for self-disclosure and friendship (Preece & Maloney-Krichmar, 2003). If the community discourages off-topic discussion, it might lose people who would like to talk with others like themselves and annoy old-timers who have gotten to know each other (Sassenberg, 2002). Thus, a community must decide whether to impose policies to control the discussion on the site, to keep it on topic.

Ren, Kraut, and Kiesler (2007) proposed Identity-based communities are likely to prefer people talk primarily about the nominal topic of the community. These communities may post no-off-topic rules as introductory messages or as frequently asked questions archives and use moderators to keep conversation on topic. One important role of moderators is to keep the discussion on track and to let it not get cluttered with irrelevant, inappropriate, or personal messages of no interest to the general readership. Ordinary members are also encouraged to give remedial feedback when someone violates the policy by posting inappropriate material. However, constraints on content make the site less appealing to people who want to know individuals better, whereas off-topic conversation and personal information on a site can undercut identity-based attachment (Postmes, Tanis, & De Wit, 2001). In contrast to the tight topical focus encouraged in identity-based communities, bond-based communities encourage personal relationships, and their introductory materials often encourage participants to post on a wider range of topics. Sassenberg (2002) suggested that online community members who feel bond-based attachment to the community will be more likely to engage in off-topic discussion.
and will be more tolerant of off-topic discussion than people who feel identity-based attachment to the community. However, Broad policies that constrain or encourage topics of conversation may fail to support individual differences in members’ types of attachment to the community or encourage a shift of attachment from topic to people as members spend more time in the community.

Ren et al. (2007) summarized some more flexible approach that could serve both types of communities. Wikipedia employs personal pages to offer an opportunity for contributors to get to know each other, whereas the discussion pages only allow topic-based discussions about the article editing. Some communities like CNET provide separate off-topic discussion boards, and the off-topic forum on the CNET site once became its most popular forum. Some communities like slashdot use member evaluations to rate posts for relevance and quality so members can then decide to view messages rated above some threshold. Automation can also be used to support similar functions. Administrators could set a threshold so the community members would only see the information most similar to the core themes in the community, or could set off this information visually. Information retrieval techniques can also be used to estimate how similar a focal thread is to other threads recently posted on a forum, and users can decide to view messages of different relevance.

2.5.3. Recruit Community Members

The process by which online communities advertise their existence and recruit members determine whether a community has enough members to pursue its goals, and also may have direct consequences for later problems the community must solve, such as user selection and retention (Kraut et al., 2012). Very few studies have addressed the recruiting process of online communities. Although there are many differences between online communities and traditional
organizations with employees, especially in terms of the formality of the recruiting and acceptance process, the research on employee recruiting may provide some insights to this issue. Coleman, Katz, and Menzel (1957) and Katz and Lazarsfeld (1966) suggested that interpersonal appeals, especially those who the target knows, are more effective at influencing attributes and adoption than through mass media. It follows that interpersonal recruiting is more effective than mass communication. The literature on the diffusion of innovation also has long recognized the role of interpersonal communication as a primary mechanism by which earlier adopters of a new product or service induce those who have not yet used it to start use it. Bass (1969) proposed a model for predicting product diffusion, the rate with which new adopters start using new products and services and the numbers using it at any given time. Montgomery (2001) used the Bass model to estimate the rate of increase in Hotmail subscribers, and the results confirmed the actual growth in subscribers are influenced by word of mouth recruiting more than advertising. Similarly, online communities use people who are already members of the community as sources to recruit new members. Many online communities, like Facebook, LinkedIn and projects in Wikipedia, recruit new members informally through their connections with existing members. One of the most successful examples of this kind of recruiting is Facebook “apps”, with which by a single click a user can invite his friends to join. Fogg and Eckles (2007) explained that this approach leverage users’ credibility with their friends in a way that is more powerful than any message directly from the community. Furthermore, some current members are more powerful conduits for new members than others. Domingos and Richardson (2001) showed that one can choose users who would be the best people to market a product to by analyzing the way opinions appear to flow along a social network. These users were the ones who would most influence other users in the social network to use the product.
Although Word of mouth recruiting is considered as more powerful, impersonal advertising also works. Roberts & Maccoby (1985) concluded that impersonal persuasion techniques can influence targets’ beliefs, affect and behavior towards a stimulus, such as a consumer product, a health intervention, political candidate or an online community. Studies of selective exposure showed that people are more likely to be exposed to beliefs that they already agree with, in part because they affiliate with people who are similar to themselves (Benoit, Hansen, & Verser, 2003). Thus, advertising may be a more effective when recruiting members for a new community, when potential members do not have prior knowledge of the community, than for an established one.

2.5.4. Select Community Members

A substantial amount of empirical studies has shown when potential members perceive themselves as having a good fit with the community, they are more likely to be attracted, pursue membership, and be satisfied with their membership and remain in the community once they join. A good fit between members and a community also lead to more benefits for the community as a whole and for existing members. However, selecting right users may be especially problematic in online communities due to the anonymity of the interaction between them and the ease of creating new identities online. Online communities also typically have no mechanism to evaluate a member’s potential before they join the community.

Kraut et al. (2012) suggested two approaches to select potential members who fit the community’s value or needs. The first is self-selection, making sure only potential members who are a good fit find the community attractive and those who are not a good fit find it unattractive. Traditional organizations provide recruits accurate and complete information about the organization, potential members can form accurate expectations, which influence their decisions
to seek employment, to join if employment is offered and to have realistic expectations once they become organizational members. In the context of organizations, this accurate and complete information is conveyed in the form of realistic job previews, in which recruiters and other members of the organization present both positive and negative job-related information to job candidates (Rynes, Bretz, & Gerhart, 1991). Online communities can use the methods to deliver realistic information about their communities, especially since they have the unique advantage that communication and production work in the community is archived automatically. While a new recruit must rely on the organization’s explicit descriptions via brochure and similar sources or rely upon word of mouth, for online community potential members can see the interactions on which these impressions are based. The archival nature of the Internet means that complete records of prior interactions (e.g. histories and talk pages associated with each Wikipedia article) among community members are available for newcomers to examine and get a realistic view of life in the community. Preece, Nonnecke, and Andrews (2004) reported a major reason that newcomers silently read posts before posting is because they are trying to get sufficient information about the group to know whether they should join or not.

Another is screening, in which the community screen out undesirable members and only allow those who are a good fit to join. Some communities judge new members by depending upon referrals from existing members. This approach is effective because referees have detailed and long-term information about both the newcomers and the community. In addition, referees have their own reputations to protect and this generally deters them from bringing an inappropriate member into a group of which they are part (Fernandez & Weinberg, 1997). Another type of screening is credential check. Discussion forum for physicians to discuss medical decisions usually asks potential members for their names and the zip code of their primary practice to
ensure that its membership includes only physicians.

Requiring potential members to complete a series of diagnostic tasks may also screen out some undesirable members. In many communities, those members who eventually go on to become leaders are distinguishable from peripheral participants in their first interactions in the communities (Panciera, Halfaker, & Terveen, 2009; Panciera, Priedhorsky, Erickson, & Terveen, 2010). Potential members who interested in open-source software development must first demonstrate their competence and commitment to the group by offering bug fixes or small enhancements before they are given committer status. Without committer status, programmers must pass their modifications to more trusted members of the group who then vet the software and decide whether to merge it with the existing code base (Ducheneaut, 2005; Von Krogh, Spaeth, & Lakhani, 2003).

2.5.5. Retain Community Members

The ability to attract and retain members frequently serves as a key metric for success in online communities (Arguello et al., 2006; Butler, 2001; Ma & Agarwal, 2007), because a stable group of participants can develop experience working together effectively, develop shared rules and norms, and agree on a common vision for the community (Ren et al., 2012). This shared experience might allow the community to work steadily toward a goal, whereas the loss of participants would mean that useful components of these shared norms and visions were no longer available to the community (Lazar & Preece, 2002). However, the research on online communities shows that these communities experience a substantial amount of turnover and that this turnover is especially high among newcomers. For example, 68% of newcomers to Usenet groups were never seen after their first post; in contrast, those who have participated even once in the past are much more likely to return (Arguello et al., 2006). 54% of developers who
registered to participate in the Perl open-source development project never returned after posting a single message (Ducheneaut, 2005). 6% of registered editors in Wikipedia never make another edit after their first 24 hours (Panciera et al., 2009).

Initial positive interactions could help retain new members. Newcomers to Usenet groups are more likely to come back for subsequent visits if others reply to them (Arguello et al., 2006). Lampe and Johnston (2005) found that new Slashdot members whose first comment received a rating from other members posted a second comment more quickly than new members whose comments weren't rated, no matter the rating is positive or negative. Forte et al. (2009)’s analysis of initial interactions between newcomers and old-timers in Wikipedia projects showed a similar pattern. New members to a project who receive more communication from existing editors during the month that they join subsequently edit more on project pages and stay active in the project for a longer period. The effects vary with the nature of the communication they receive. Personalized messages, such as comments about the newcomers’ background or requests to work on a particular task, lead to more powerful effects than generic ones, in which the newcomer receives a standardized message such a welcome-to-the-project template. Wikipedia explicitly encourages gentle treatment of new editors, with its "Don't bite the newcomer" policy. Newcomers whose first edits were reverted (a reversion occurs when a document is restored to its previous version, negating someone’s edits) are especially likely to leave the community (F. Zhu & Zhang, 2006). To reduce the negative impact, Wikipedia editors are encouraged to “assume good faith” by the editor they are reverting, and explain their rationale with details for the reversion so as not to deter a potential contributor.

Although the most common view of turnover in online communities, similar to that for organizations, is that it relates negatively to performance, some research also suggested that
moderate levels of turnover may benefit organizations or communities that lack the time or resources to screen and select members carefully. Especially for online communities, some turnover may be necessary to allow new members to join. Online communities are not technically limited to a finite size, but people tend not to join once the membership or communication levels are perceived to be too high (Butler, 2001; Kuk, 2006). Groups that are isolated from outside perspectives can develop biases and insular thinking that leave them susceptible to overconfidence about the group’s ability to collaborate effectively (Schultze & Leidner, 2002). Thus, some turnover might be necessary to create an influx of unique contributors with new ideas, skills, and information. Similarly, Kane (2009) investigated the collaboration associated with 2,065 Wikipedia articles, and concluded that moderate levels of membership turnover are desirable in peer production communities, because it brings new information and abilities to the community, without compromising its ability to retain the content it has generated.

2.6. Community Activities at Community Growth Stage

Research investigating community dynamics leading to continued functioning of a mature online community falls into two categories. The first type of research focuses on motivations of individual members in the community, since the survival of online communities relies on the continuous participation of individual members. The second type of research investigated how the community-level characteristics influence the success of online communities. Research has explored three main types of community-level characteristics: composition (i.e., the makeup of the community, such as community size), structure (i.e., the patterns of the relationship among the members, such as leadership structure or governance structure), and self-management.
2.6.1. Motivate Contributions

The first type of studies investigated the reasons why individuals contribute to the communities, identifying a wide range of motivations, ranging from fun to helping to reputation building. Dholakia, Bagozzi, and Pearo (2004) provided evidence for six categories of benefits of making contribution to online communities: getting information, giving information, reputation building, relationship development, recreation, and self-discovery. Five major themes were identified in interviews of contributors to Knowledge-iN, a large South Korean Q&A site (Nam, Ackerman, & Adamic, 2009), including helping others, learning, promoting their business, recreation and accumulating points.

Research on Wikipedia and open source software projects suggested that a mix of intrinsic motivation and extrinsic rewards drives participation. Top contributors may have strong intrinsic motives to participate (Panciera et al., 2009). Nonmonetary rewards such as acknowledgements (Ling et al., 2005; Rashid et al., 2006), badges (Anderson, Huttenlocher, Kleinberg, & Leskovec, 2013; Restivo & Van De Rijt, 2012), and gamified feedback (Deterding, Sicart, Nacke, O’Hara, & Dixon, 2011) have also been shown to increase engagement of users. Lakhani and Wolf (2005) surveyed open source software developers, identifying motivations such as intellectual stimulation, desire to improve programming skills, and adherence to the principles of open source software. Nov (2007) found that fun and adherence to the principles of open source were leading motivations for Wikipedia editors, and that the fun motivation was moderately positively correlated with higher self-reported participation. Oreg and Nov (2008) surveyed Wikipedia editors and open source contributors, finding differences in motivations between the two domains: contributors to open source software were more motivated by gaining reputation and self-development compared to contributors to Wikipedia, who were more motivated by altruistic
reasons, suggesting motivations could vary based on the community type (Moore & Serva, 2007).

Studies in this category suggested two ways to increase community members’ motivations to make contributions: by enhancing intrinsic motivations and extrinsic motivations. Intrinsic motivation refers to the internal satisfaction received from the process of performing behaviors. Kankanhalli, Tan, and Wei (2005) showed that individuals would share knowledge in organizations in order to gain intrinsic benefits. Lin (2007) also observed that intrinsic motivation of organization members is positively related to knowledge sharing intention. Additionally, Wasko and Faraj (2000) found that individuals who enjoy sharing knowledge are likely to be the most active contributors of valuable knowledge to a virtual community. Coleman's (1990) term for “true believers” in a collective good who contribute for purely intrinsic value beyond rational expectations, which has been proven in open source software development communities, where many contributors claimed themselves as “zealots” (Lakhani & Wolf, 2005). Yang and Lai (2010) concluded that internal self-concept, which refers to the force that drives individuals to pursue an activity that meets their inherent standards, was the key to motivate knowledge sharing on Wikipedia.

While intrinsic motivation indicates the pleasure and inherent satisfaction derived from a specific activity, extrinsic motivation focuses on the goal-driven reasons, such as rewards or benefits earned when performing an activity. The rewards an online community can offer vary from extrinsic rewards including gift, social recognition, feedback, to intrinsic rewards such as praise and respect. Providing reward had proven to be effective to motivate community members’ contribution, making the communities more active and more successful (Andrews, 2002; Butler, Sproull, Kiesler, & Kraut, 2002; Chan, Bhandar, Oh, & Chan, 2004; Hall & Graham, 2004; Hars
In online communities, members may value reputation or status markers because these rewards can be transformed into an investment, for example, self-marketing for programmers to advertise their capabilities (Hars & Ou, 2001), or changing how other people interact with them. Tausczik and Pennebaker (2012) investigated what reasons do users contribute to Math Overflow, a site dedicated to research-level mathematics, and the results shown building reputation is an important incentive, even though users do not report this in the survey. And among members of a professional legal association, contributions to the association’s online message board were significantly predicted by members’ perceptions that doing so would enhance their professional reputations (Wasko & Faraj, 2005). Li, Huang, and Cavusoglu (2012) examined the value of badges (rewards earned based on certain activity, for example, users earn the badge “Enlightened” when they are the first to answer a question and that question is accepted with score of 10 or more) on user activities in Stack Overflow, and found badge system is able to motivate users to contribute more in all types of activities. They also pointed out other activities which are not specified in the requirements of earning a badge are also affected by the status of getting the badge.

Besides individual incentives, previous studies also stressed the importance of the initial period of socialization in online communities. A successful early socialization experience is associated with, and sometimes even predicts, increased engagement in mailing lists (Backstrom, Kumar, Marlow, Novak, & Tomkins, 2008), newsgroups (Joyce & Kraut, 2006), social networks (Burke, Marlow, & Lento, 2009), and Wikipedia (Choi, Alexander, Kraut, & Levine, 2010; Morgan, Bouterse, Walls, & Stierch, 2013). Strong motivational factors, perhaps in conjunction with individual-level skills, may be the cause for both a successful early socialization stage and a later long-term participation. To further establish a causal connection, controlled and field
experiments on groups of limited size have been performed, with encouraging results: sharing in a digital information good is increased by social incentives (Cheshire, 2007), and personal messages improve the retention of newcomers to Wikipedia who had their edits rejected (Geiger, Halfaker, Pinchuk, & Walling, 2012).

2.6.2. Maintain Community Size

The communication volume from many members can overwhelm people with limited attentional resources and result in high turnover in the group. Jones, Ravid, and Rafaeli (2004) analyzed a large sample of Usenet newsgroups and concluded the more messages posted in a group during a month, the smaller was the proportion of posters who returned in the subsequent month. The study conducted by Butler (2001) also suggested similar results that larger online groups with more traffic had more turnover. Their works on the effects of size and numerous posts suggested that attentional overload is a problem in many online communities, and that members may be driven away from communities they like when they perceive it has become too hard to find the information or interactions they seek. However, it is not clear what levels of size overload and negative impact will occur, whether the relationship is linear or otherwise, and whether the impact of size affects core and peripheral members differently.

Large community size could also lead to diversification in community purposes and member preferences. Creating subgroups can potentially undercut the overarching goal of the community as a whole. As member contributions reach a new height, the formation of subgroups and the permeation of control to facilitate subgroup discussion help decrease information and administration overload for members and operators (Andrews, 2002). Jones and Rafaeli (2000) emphasized the need to allow subgroup formations and to facilitate interaction and discussion on different subtopics of interest or for different types of members. For example, Maloney-
Maloney-Krichmar and Preece (2005) found that in an online community of support for patients undergoing treatment it is important to provide different spaces, one for patients and one for members of their families, in order to provide a sense of intimacy, and suggested strong subgroup activity are key factors in the stability and vitality of the community.

2.6.3. Decide Community Structure

An online community’s core members, defined by the power law in contribution distribution, are the critical mass of the community. Members of the core group often perform a large proportion of community building and maintenance work such as infrastructure maintenance, writing and reading messages, and moderating and policing the site. For example, the top four percent of the developers in the Apache server project contributed 88% of new lines of code (Mockus, Fielding, & Herbsleb, 2002). Stvilia et al. (2008) found that member participation in Wikipedia exhibit a power law pattern. However, as the size of the administrator group increasing, it became difficult to communicate effectively across the administrator group and keep its members updated and aligned with Wikipedia’s policies and established practices. Kittur and Kraut (2010) also concluded that much of the work is done by a core group of contributors is a core coordination characteristic of many successful wikis and open source software communities. Having the work concentrated in a small group of contributors can have a number of benefits. Communication needs are reduced, since many topics require discussion only by the core group. Similarly, consensus building can be easier since fewer stakeholders are involved. The core group is also more likely to develop a common view or shared mental models of the work that needs to be accomplished even without explicit communication. The core can also act as leaders by setting direction and creating a framework for the article, which allows more peripheral editors to contribute more effectively (Kittur, Lee, & Kraut, 2009).
Community members specialize in ways not only simply the amount of work they do, but also the social roles they carry in the community. The concept of social role describes the intersection of behavioral, meaningful, and structural attributes that emerge regularly in particular settings and institutions. Social role of community member have mainly been studied online in the context of text based discussion spaces, where a variety of roles have been identified, including local experts, answer people, conversationalists, fans, discussion artists, flame warriors, trolls, and even lurkers (Welser et al., 2011). Relatively little research, however, has gone into how online communities define and manage specific roles in coordinating members’ work. Online communities have few clearly defined roles; those that exist, such as administrator and monitor, are primarily used to grant extra powers such as the ability to block troublesome users from editing and protecting controversial pages from vandalism. Specialization of roles is also commonplace in large OSS projects. When developers join OSS projects, they are often rewarded for specializing in one area (Von Krogh et al., 2003). Moon and Sproull (2000) described the process by which authority in Linux was gradually transferred from the project leader to a set of lieutenants called “maintainers”. Rather than developing new code, these lieutenants were responsible for reviewing other developers’ code, integrating code into patches, and ferrying the result up to Torvalds for approval. Other roles may include bug triagers, quality assurance leaders, and release managers (Mockus et al., 2002). Developers may self-assign these roles or be assigned one by the leadership in a given OSS project. Kriplean, Beschastnikh, and McDonald (2008) showed that informal awards (Barnstars) are used to encourage and reward different types of valued work, and suggested that these Barnstars may be used to identify existing or emerging types of work that may correspond to different roles in Wikipedia. Though formal roles are few, peer production communities like Wikipedia recognize a number of
informal roles as well, including substantive experts, technical editors, vandal fighters, and social networkers (Welser et al., 2011), or reader, contributor, collaborator, and leader based on the level of participation (Preece & Shneiderman, 2009). These informal roles provide an open structure that supports coordination in peer production communities, which marked by breaking large, complex tasks into small, independent modules and providing members with a wealth of tasks that they are interested in.

2.6.3.1. Leadership Structure

As online communities evolve, their leadership structure often changes from vertical leadership to more distribute. Former leaders may quickly find themselves outmatched by the amount of work to be done. As a result, new governance structures involving decentralization or specialization may be created to help the leaders manage their workload. Many OSS projects evolve a more decentralized, distributed governance model as they mature. Research about Linux shown how governance in the Debian distribution of Linux became more decentralized, and authority more distributed, over time (O’Mahony & Ferraro, 2007). Nakakoji, Yamamoto, Nishinaka, Kishida, and Ye (2002) referred to this leadership approach as council-style central control. They position council-style central control alongside cathedral-style central control, in which a project leader maintains tight control over the direction of a project, and bazaar-style decentralized control, in which loose control facilitates many variations via forking. They also draw a connection between leadership approaches and the project’s purpose. For example, more original projects tend to operate via cathedral-like central control. Decentralization and specialization have also been observed in open-content Wikipedia. Forte et al. (2009) found that elaborate governance structures have evolved in the English-language Wikipedia to manage the massive influx of new users and content. What began in 2001 as a
project led by the founder and the editor-in-chief now includes a multi-tiered hierarchy of access levels. Moreover, governance in Wikipedia is increasingly decentralized. Administrators wield more local authority and sub-communities called “WikiProjects” embrace conflicting policies. Some editors appoint themselves as “Maintainers” of certain articles to which they are primary contributors, demonstrating leadership, commitment, and even territoriality (Thom-Santelli, Cosley, & Gay, 2009).

Zhu et al. (2011) operationalized four leadership behaviors from Pearce and Conger’s definition—providing positive feedback, providing negative feedback, directing, and social exchange—and developed a machine learning model that searched for examples of these behaviors in 4 million messages sent between Wikipedia editors. The results suggested strong evidence of shared leadership in Wikipedia, with non-administrators performing many leadership behaviors. In a follow-up study, Zhu, Kraut, and Kittur (2012) elaborated on their theoretical framework, connecting the four aforementioned leadership behaviors to their theoretical bases. Messages containing positive feedback are indicators of transactional leadership, negative feedback indicates aversive leadership, and directive messages are evidence of directive leadership. All three behaviors are classified as task-oriented behaviors, while the fourth leadership behavior, social exchange, is evidence of person-based leadership. Finally, they defined the concept of leader “legitimacy” as leaders who “occupy formal leadership positions in an organization, volunteer community or other social system.” Their legitimacy “stems from the selection process, whether they are appointed by supervisors, elected by the membership or appointed because they fulfilled more or less explicit criteria”. They operationalized leader legitimacy in Wikipedia as editors with administrator status, since administrators are elected through a formal process. Regarding effectiveness, they focused on editors’ effectiveness at
influencing others, rather than the overall effectiveness of their efforts on improving Wikipedia. They found that while legitimate leaders (administrators) were more influential overall, non-admins also substantially influence others via leadership behaviors. In particular, transactional leadership (positive feedback) and person-oriented leadership (social exchange) were shown to increase motivation, while aversive leadership (negative feedback) decreased motivation.

There is limited evidence of decentralization and specialization in other areas of online creative collaboration. In the Scratch online animation community (Kafai, Roque, Fields, and Monroy-Hernandez (2011) identified successful, emergent collaboration models such as partnerships and team efforts, which functioned “through a shared leadership model that spread the responsibilities of organization, decision-making, and development across its members”.

2.6.3.2. Governance Structure

Governance generally refers to a system for organizing the policies and rules that regulate people’s behavior in a particular place. Research on open source software development has created an interest in understanding the governance of software development projects due to the proliferation of open source software and a strong hacker cult observed in the open source environment. Demil and Lecocq (2006) provided one of the most prominent descriptions of the governance of open source software development, coining the term “bazaar style governance” to highlight how a variety of mechanisms contribute to controlling and guiding these developments.

A review of the literature on the governance of open source software development (Markus, 2007) highlighted the importance of considering structures, processes, and rules (informal, formal, encoded), but also mechanisms of trust and control as viable mechanisms providing control and guidance to the open source software development. Specific governance mechanisms investigated in open source software development research include formal roles such as project
leaders or core groups (Sharma, Sugumaran, & Rajagopalan, 2002), and also formalized
decision-making and sanctioning processes (e.g., banning members) (Osterloh & Rota, 2004).
Informal mechanisms that contribute to controlling and guiding the software development
process include aspects of social pressure (Sagers, McLure-Wasko, & Dickey, 2004), informal
leadership, shared rules, norms, and communication protocols (Bonaccorsi & Rossi, 2003).
O’Mahony and Ferraro (2007) emphasized how the software development process was governed
by democratic and meritocratic mechanisms at the same time: the community as well as
particular individuals control and guide the open source software development.
Recent work has begun to understand Wikipedia’s governance structure in terms of Ostrom’s
(1990) work on collective self-governance (Forte & Bruckman, 2008; Viégas et al., 2007).
Wikipedia’s governance structure includes (1) graduated dispute resolution mechanisms (Forte &
Bruckman, 2008), where violations of policy can be punished through blocking and banning, (2)
an elected board of Wikipedians that carries out judicial-like functions such as the interpretation
of policy and formal arbitration (Forte & Bruckman, 2008), and (3) stringent formal processes
for becoming an administrator and elevating a page to “featured” status (Viégas et al., 2007). The
development of policies and guidelines on Wikipedia is based on the open content creation
principles of distributed and open editing. Hence, policy creation follows a “self-similar process”
where the development of a regulatory framework is based on the same patterns as the resource
that is to be regulated. As a consequence, the regulatory framework remains fluid and can be
adjusted to emerging requirements (Forte & Bruckman, 2008). By citing and referring to these
policies on talk pages, individuals selectively “use” these policies to influence the content
creation process as part of the distributed peer-regulation (Beschastnikh, Kriplean, & McDonald,
2008; Forte et al., 2009). Another governance aspect that has received particular attention is the
establishment of formal roles among contributors. Individuals are nominated as administrators or to other formal roles that grant them particular authority to enforce policies (Forte & Bruckman, 2008) and are thought to help stabilize the social system (Kittur et al., 2007). Other formal governance mechanisms include dispute resolution and arbitration processes where established procedures are used to solve conflicts among contributors (Forte & Bruckman, 2008).

As research has to systematically investigated the importance of formal structures, policies, and roles for governing online communities, the informal mechanisms have received much less attention. Studies have been conducted to explore informal governance mechanisms on Wikipedia but still in a very limited number for other kinds of online communities including social Q&A. Bryant et al. (2005) and Forte et al. (2009) described how social norms on the Wikipedia platform help guide and control the behavior of contributors. They also highlighted the role of “old-timers” who are instrumental in conveying these social norms to “newcomers” to the open content creation platform. Such informal mentoring, as well as other discussions regarding policy, planning, and coordination of the editing effort, is facilitated by talk pages, which allow for text-based interaction and direct exchanges among editors thus benefit the collaborative creation process (Black, Welser, Cosley, & DeGroot, 2011; Viégas et al., 2007).

Schroeder and Wagner (2012) identified a wide range of formal and informal mechanisms that help guide and control Wikipedia article development process, and confirmed policies (Forte & Bruckman, 2008) and talk page discourse (Beschastnikh et al., 2008; Viégas et al., 2007) as important mechanisms that contribute to the governance of open content creation. They also pointed out those mechanisms related to informal attributes of individuals has not been fully recognized.

Another gap of the current governance research is its focus on investigating exceptional
situations instead of common ones (Schroeder & Wagner, 2012). Focusing on exceptional circumstances provides valuable insights but does not take into account that, in most cases, content development does not follow such exceptional trajectories and does not trigger such formal interventions (Reagle, 2007). Viégas et al. (2007)’s elaboration on governance mechanism is focused on cases of outstanding content. Kriplean et al. (2007) investigated governance with regard to content that is heavily discussed among contributors. Researching the mechanisms used for dealing with individual misbehavior, such as vandalism (Kittur et al., 2007) or violation of rules (Butler, Joyce, & Pike, 2008), is also of great interest, but only applies to a very small number of instances.

2.6.4. Coordinate Work

Coordination in online peer production communities means the act of managing interdependencies between activities (Malone & Crowston, 1994). A lot of useful work in peer production communities does not involve direct content creation. Kriplean et al. (2008) found that editors give one another specialized awards called Barnstars to recognize a variety of valuable contributions on Wikipedia beyond editing articles: from meta-work such as developing specialized tools, to work that sustains the community such as conflict mediation. Morgan et al., (2013) concluded community support and meta-content work coordinated through alternative WikiProjects become even more important to the health of the modern Wikipedia ecosystem. To be successful, community members need to coordinate these work activities in both broad and detailed ways.

Direct communication is the most basic coordination mechanism. Take Wikipedia as an example, discussion pages (talk) are routinely used by editors to exchange opinions about potential changes, by administrators to communicate management information, and by those
outside the article’s editorial group to ask questions or solicit assistance for other articles (Stvilia et al., 2008). This form of coordination artifact is very effective in creating high quality content: the featured article set had significantly better developed discussion pages than the random set (Stvilia et al., 2008), and especially prevalent while an article is in a formative stage: on average more than half of the edits to an article during its first week are to its discussion page rather than to the content of the article, with this number quickly dropping as the article develops (Kittur & Kraut, 2008). The effectiveness of such direct communication as a coordination mechanism may also interact with factors such as who is communicating. Discussion among anonymous editors is associated with increased conflict, while discussion among registered editors is associated with reduced conflict (Kittur et al., 2007).

Kittur and Kraut (2010) argued that communication between editors on users’ talk pages is also an important but less studied coordination mechanism. Some of the edits to these pages are spill-over from article talk pages, with detailed discussion and negotiations about the article happening on the involved parties’ user talk pages. However, these pages additionally support different kinds of coordination that are not necessarily tied to the content of specific articles. For example, editors engage in activities such as requesting help from each other, notifying each other about shared interests (e.g., if an article that they both edited is being proposed for deletion), or discussing standards that should apply to multiple articles.

In addition to direct communication, coordination can occur through the development and use of policies and precedents. For example, Wikipedia has developed an extensive policy system to govern areas ranging from the process of becoming an administrator to what constitutes an encyclopedic article to methods for managing conflict and consensus building to defining plagiarism (Beschastnikh et al., 2008; Burke & Kraut, 2008; Butler et al., 2008; Forte &
Bruckman, 2008).

In general, policies and procedures have not been quantified and studied to the same degree that communication has in Wikipedia. One way to quantify the importance of policies to examine Wikipedia namespace and its corresponding discussion pages, where policies and procedures are edited and discussed. Beschastnikh et al. (2008) analyzed discussions to understand how policy was used to support coordination activities in Wikipedia. From their perspective, the work of coordination is critical to the process not only of producing content and arriving at consensus, but also provides opportunities for volunteers to interact, define roles and use power relationships, which are important features of group health. Butler et al. (2008) identified 44 wiki pages in the “Wikipedia official policy” category and 248 in the “Wikipedia guidelines” as of 2007. The Wikipedia namespace also includes a variety of other kinds of coordination-oriented pages, such as requests for assistance, noticeboards for editors to bring issues to the attention of administrators, and discussions of whether to delete particular articles. The Wikipedia namespace is also home to Wikiprojects, which are subgroups in Wikipedia oriented around a certain topic or task that organize and coordinate their members to improve topic-related articles or complete topic-related tasks (Forte et al., 2012). Kittur and Kraut (2010) quantified policy and procedure work for each of the wikis by looking at the wiki namespace and its corresponding talk namespace and identified an increasing influence of policy and procedure edits of use on Wikipedia.

Use of collaborative technologies could also benefit work coordination in peer production communities. Cosley et al. (2006, 2007) developed the intelligent task routing technique, which (in the general case) leverages a user’s behavior and demonstrated preferences and matches these contributors to work that would be valuable to the community. Cosley et al. (2006) studied how
often community members correct information on MovieLens by matching members with movies they were likely to edit. The study compared four simple strategies for choosing movies based on the collective effort model: choosing random movies, choosing movies the person was predicted to like, choosing movies that were missing the most information in the database, and choosing movies the person had previously rated. The results shown choosing rated movies performed best. This experiment suggested that task routing was useful for peer production communities. In their later work, Cosley et al. (2007) combined users’ edit histories, coediting histories with other users, and lexicographically similar articles to form a user profile to match them to work. The results showed a four-fold improvement in recommendations when compared to randomly assigning articles. Zhou, Lyu, and King (2010) considered question routing on social Q&A sites as an information retrieval task, and developed local and global features which capture different aspects of questions, users, and their relations. They also examined how different feature groups contribute to question routing and discovered question-user relationship play a key role in improving the overall performance. The effect of question-user relationship also proved what economics and social psychology suggested, that reducing the cost of contributing could increase people’s motivation to do work for a community.

2.6.5. Conflict Resolution

In any online community, conflicts and disagreements between community members or groups are inevitable. While in particular situations certain types of conflict can be productive (Jehn, 1995), conflict generally has been found to lead to negative outcomes, both for the task and for the people involved (Jehn, Chadwick, & Thatcher, 1997). Thus decisions must be made regarding conflict resolution, such as determining whether contributions are appropriate, interpreting and applying policies, upholding social norms, responding to deviant behavior. A
wide variety of conflict resolution strategies can be applied, including simply providing guidelines and advice about decision-making, establishing venues for community discussions aimed at finding a group consensus, and perhaps in extreme cases, organizing formal proceedings that resemble arbitration hearings or courtroom trials. Jensen and Scacchi (2004) studied conflict negotiation and resolution strategies in the Netbeans.org community, a Java-focused open source software development community backed by Sun Microsystems. Conflicts in the Netbeans.org were resolved via community discussion mailing lists. The process usually begins when one member announces dissatisfaction with an issue in development. Those who also feel concern with the particular issue then write responses to the charges raised. At some point, the conversation dissipates, usually when emotions are set aside and clarifications have been made that provide an understanding of the issue at hand. If the problem persists, the community governance board is tasked with the responsibility of resolving the matter. Using History Flow, Viégas, Wattenberg, and Dave (2004) examined the history of selected articles on Wikipedia and found that edit wars, a symptom of conflict, are quite prevalent and not limited to controversial topics. They also found Wikipedia editors try to resolve disagreements via their comments on why they edited something on a page: comments on consecutive revisions are not only a summary of edits, but also read as a conversation editors used to address possible objections or direct questions to each other. The talk pages function as extensions of edit comments, but afford more room for people to argue their positions. When editors cannot convince others of why their edits are valid via the comments they leave, the discussion escalates into the talk pages. Moreover, they noted that these edit wars tended to be connected with increased activity on the discussion pages. Stvilia et al. (2008) confirmed that talk pages and article edit histories play a key role in coordinating article creation, identifying vandalism,
resolving conflicts. Kittur et al. (2007) presented methods to characterize conflict in Wikipedia at the global, article, and user levels. The results of their study shown an effective way to resolve conflict is to increase the number of users involved in editing the article, rather than have the same few people arguing back and forth. They also concluded that focusing community attention on controversial pages could help to resolve conflict. In their later work, Kittur and Kraut (2010) again emphasized conflicts in wiki systems depend not only the number of contributors involved, but also on the dependencies incurred by their contributions. There is a decrease in conflict when the size of the information space grows, as editors are not forced to interact as often. This suggested that the density of the information space, as opposed to the absolute number of contributors, was a key determinant of conflict. Policies and procedures were associated with less conflict when smaller numbers of editors worked on content, but were associated with increased conflict when many editors were involved. Conversely, communication and concentration were more associated with reduction of conflict as more editors were involved.

2.6.6. Quality Control

Not all contributions to a community are valuable. Off-topic conversation, newbie questions, incorrect FAQ entries, flames and trolls, spam, and content-free posts like “just testing” all represent contributions that most members would like to avoid. Online communities employ various approaches to control the quality of their knowledge repositories, which can be mainly classified in two groups: quality control approaches on content and approaches on users.

2.6.6.1. Collaborative Peer Review

One design used by some online communities to control content quality is the peer review mechanism. After a user submitted content, other must review the submission and take appropriate action if the submission does not meet quality requirement or violates community
policies. Such review mechanism, although implemented via different ways, has been proven effective in discouraging low value contributions and motivating valuable contributor in peer production communities (Cosley et al., 2005). Members of Slashdot read and comment on stories posted by editors and other members’ comments, and are allowed to moderate others’ comments with a +1 or -1 rating or a descriptor such as Funny or Redundant. Moderations are aggregated by this way and readers can choose to see only highly rated comments or to see everything, a scheme Lampe and Resnick (2004) call distributed moderation. Another example is the Open Directory Project. That site relies on tens of thousands of volunteer editors to determine which links should be included in a human-edited directory similar to Yahoo. Acceptance as a volunteer requires application and not all are accepted. The quality relies on a peer review process based substantially on seniority and engagement as a volunteer. Similarly, MovieLens asks members to help build its movie database by entering movie information and checking information entered by others. The experiments using Movielens (Cosley et al., 2005) proven peer review/oversight can increase both the quantity and quality of contributions to a peer production community while reducing antisocial behavior, and peers are as effective at oversight as experts.

2.6.6.2. Collaborative Editing

Collaborative editing has been used successfully in different types of content productions, such as science collaboration (Persson, Glänzel, & Danell, 2004) and software development (Dabbish, Stuart, Tsay, & Herbsleb, 2012), and it has been widely believed that Wikipedia’s success in producing articles with high quality is largely attributed to the open collaboration model that allows any person to participate in the editing. For example, Kittur and Kraut (2008) examined how the number of editors in Wikipedia and the coordination mechanisms could affect the article
quality. They concluded that having more editors is more likely to improve an article’s quality if appropriate coordination techniques are applied. To obtain high quality content, there is a recent trend for social Q&A sites to incorporate Wikipedia-like collaborative editing function, that is, allowing questions and answers to be collaboratively edited by the whole community. For example, Stack Overflow, which features computer programming related questioning and answering, claims that “(Collaborative) Editing is important for keeping questions and answers clear, relevant, and up-to-date” and “This site is collaboratively edited, like Wikipedia. If you see something that needs improvement, click edit!” Li, Zhu, Lu, Ding, and Gu (2015) analyzed five years’ archival data of Stack Overflow and concluded the benefits of adopting collaborative editing to social Q&A outweigh its potential drawbacks: each substantive edit from other users can increase the number of positive votes by 181% for the questions and 119% for the answers. On the other hand, each edit only decreases askers and answerers’ subsequent contributions by no more than 5%.

2.6.6.3. Entry Barriers

When content comes from users, getting high-quality users as well as reducing deviant antisocial behavior in peer production communities is another equal important concern. Some online communities introduce barriers to entry as a quality control approach. For example, users are required to perform non-trivial tasks before being given full membership privileges. Many social networking sites like Facebook and LinkedIn make new users complete a profile containing personal information, preferences, and a list of friends or colleagues. Social Q&A sites like Quora used to only allow people who have references from community members to join. In experimentation with entry barrier in Movielens, Drenner, Sen, and Terveen (2008) observed users who overcame the barrier were more committed to the community, and did more and better
work in the long term. Also the design of the barrier itself was effective at shaping user behavior. However, such strategy comes with a cost. Drenner et al. (2008) also pointed out that subjecting users to a more arduous initiation process indeed causes some to forego participating in the community. The trade-off of quality control design like introducing entry barriers should be carefully evaluated since it may cause tensions between managing quality and encouraging contribution. For example, Halfaker, Geiger, Morgan, and Riedl (2013) found that several changes the Wikipedia community made to manage quality and consistency (e.g., the use of anti-vandalism tools), although successfully preserve the content quality, cause the decline in the number of active contributors.

2.6.6.4. Recognition and Privilege System

Another quality control strategy many online communities employ is the member recognition and privilege system. Take Wikipedia as an example, an administrator or a bureaucrat is selected based on their performance and knowledge of Wikipedia processes and ranked higher than regular editors in Wikipedia’s power structure. These administrator and bureaucrats have more power in community activities, including both content and user control. Yahoo! Answers’ reward system assigned users to different levels and encouraged them to contribute high quality content that can earn them recognition and social capital (Shah, Oh, & Oh, 2008). The privileges system, which associated with rewards, has more directed effect on quality control since it controls what a community member can do. For example, users who have earned 5000 points are granted the “edit questions and answers” privilege thus can edit anyone’s post in the system without it going through peer review. Stack overflow has very detailed privilege system, which can be categorized into four groups: milestone, moderation, communication, and creation. Other communities’ privileges system could be much simple, for example giving different levels of
power to site managers, moderators, registered users and guests. However, The intuition behind those designs are the same—let higher quality, more experienced users to perform more control level tasks and take more responsibilities thus to guarantee the quality of content the communities produced.

2.6.6.5. **User Intervention**

User intervention is another approach used to improve the quality of user-generated content. Lampe and Resnick (2004) found that the behavior of new Slashdot users was affected by a combination of their viewing behavior, the moderation feedback they receive, and replies to their comments. In the context of open source software development, Ducheneaut (2005) observed a process by which new contributors develop their identities as software craftsmen as they go through professional “rites of passage”. Bryant et al. (2005) studied how people become regular contributors to Wikipedia. They use activity theory and the notion of legitimate peripheral participation in communities of practice to analyze interviews with nine experienced Wikipedians. Contributors progress from novices who work mostly on editing articles that interest them to experienced users who work both on articles and on meta-level tasks such as mediating disputes, determining policies, and building the Wikipedia community. One important way novices grow toward doing meta-level tasks is by discovering tools useful for those tasks in the course of their normal editing activities. Antin and Cheshire (2010) described the phases through which Wikipedia editors move from passive readers that learn about Wikipedia, to novice editors who focus on topic-specific activities, and finally to committed Wikipedians who take a broader community perspective and engage in administrative roles and responsibilities. This three-stage path does not describe the path of participation for all (or even most) Wikipedians, but instead describes a common path to the more committed roles.
2.6.7. Inter-Community Relationship

Another factor could influence the survival of is inter-community relationships, regardless of which stage a community stays. All online communities exist within a larger population of communities, with which they cooperate and compete. The relationship among these communities can affect the survival of all communities within a Niche. However, research on the inter-community relationships is quite neglected. Stvilia, Al-Faraj, and Yi (2009) concluded different Wikipedia communities have different quality models and the usefulness of edit-based metrics differ across Wikipedia communities in auto quality assessment. Wang et al. (2013) took a competition view of membership overlap. They argue that an individual’s time is scarce. When multiple online communities rely on the participation of the same members, the time members spent on one community takes time away from another community, thus reducing the chance of survival for both communities. Similar cross-community studies in other areas of peer production, or studies comparing across different types of peer production, have remained challenging and rare.

2.7. Content Quality Assessment on Social Q&A Communities

2.7.1. User-identified Criteria

Several previous studies have analyzed user-identified criteria of content quality on social Q&A communities (Chai, Potdar, & Dillon, 2009; Choi & Shah, 2016; Emamjome, Rabaa’i, Gable, & Bandara, 2013; Ge, Helfert, & Jannach, 2011; S. Kim, 2010; Shah & Pomerantz, 2010; Sun, Zhao, & Zhu, 2015; Zhu, Bernhard, & Gurevych, 2009). Participants recruited for these quality assessment studies ranged from subject experts to ordinary users. User studies require more time and effort but quality criteria proposed by Q&A users can better reflect their information needs and understandings of the information problems. More recently, a new variation of user-based
quality assessment has emerged in which the main goal is to examine if quality criteria identified from general Q&A sites can be transferred to Q&A features on other social networking platforms (Jenders, Krestel, & Naumann, 2016; Jeng, DesAutels, He, & Li, 2017).

2.7.2. Quality Features

Comparing to user studies, identifying high-quality content by discriminative feature sets is a well-studied problem. Posts from social Q&A sites are represented by a particular set of features and a classifier is applied to label best answers based on those features in earlier works. Features can be content or semantic based, including content length, content metadata (rating, creation date, etc.), grammatical errors, question topic, comments. Agichtein, Castillo, Donato, Gionis, and Mishne (2008) reported that answer length was dominant over other features. Burel, He, and Alani (2012) introduced a new feature group representing relations between answers and follow-up comments. The results showed that length features are not correlated with selecting the best answers, and that features based on the rating of the answer can be a good predictor of the best answers. Some approaches relied on the expertise and importance of the person who answers questions (Neshati, Fallahnejad, & Beigy, 2017; Van Dijk, Tsagkias, & de Rijke, 2015). Such assessment is usually performed by applying link-based algorithms, such as ExpertiseRank which incorporates user expertise with PageRank, and HITS for measuring popularity or connectivity of users.

Another line of research focused on ranking posts. Bian, Liu, Agichtein, and Zha (2008) developed a ranking framework for quality assessment of factual answers, combining textual and non-textual features. The textual features used in the study were: length features like question length, answer length, question/answer length ratio; and linguistic characteristics like number of unique words, number of frequently used words, number of non-stop word overlap. The non-
textual features used were askers’ reputations, answerers’ reputations, and user rating. Findings suggested both textual and non-textual features are equally significant for users to select the best answer among others. Similar findings were confirmed by Blooma, Goh, and Chua (2012). Surdeanu et al. (2008) applied the concept of relevance to social Q&A, identifying textual and non-textual features of relevance, and measured the correlations between question and answer pairs to further evaluate the answer quality. Yao et al. (2015) confirmed a strong correlation existing between the number of votes of question and answer quality in automatic answer ranking.

More recent work usually combined large sets of textual and non-textual features to build multidimensional classifiers or machine learning algorithms to identify or predict high-quality content. (Blooma et al., 2012; Burel et al., 2012; Dalip et al., 2013; Molino, Aiello & Lops, 2016; Neshati, 2017; Ponzanelli, Mocci, Bacchelli & Lanza, 2014; Toba et al., 2014; Yan & Zhou, 2015; Yao et al., 2015). Dalip et al. (2013) adopted an approach based on Random Forests to rank answers from Stack Overflow. They used 186 features in eight groups and concluded that review and user features are most important in the Q&A site, while readability, network, and relevance features are not very useful. A new trend is to utilize the mutual quality relation between questions, answers, and comments to detect high-quality posts. Liu et al. (2015) proposed a co-training model to predict answer quality with non-textual features. Neshati (2017) confirmed that considering dependency between quality of questions and answers can significantly improve the performance of a prediction task.

2.8. Activity Theory

Activity Theory in essence is dynamic and evolving with its application in empirical studies (Nardi, 1996). The earliest version—Vygotsky’s Activity Theory—studied human consciousness

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and proposed that it was mediated by culture, that is, abstract tools, such as language, signs, and symbols. The structural representation of Vygotsky’s Activity Theory consists of two components, subject and object, the relationship between which is mediated by tools. The second version—Leont’ev’s Activity Theory—proposed that human consciousness was mediated by activities, and expanded the concept of tools to include both abstract and physical tools. Unlike Vygotsky’s version concentrating on individual activities, Leont’ev introduced the concepts of division of labor and cultural-social context, distinguishing between individual and collective activities. The latest version—Engeström’s Activity Theory—added two new components, community and outcome. The relationship between subject and community is mediated by rules and norms, and the relationship between object and community is mediated by division of labor. Compared to the previous two versions, Engeström’s places an emphasis on identifying the interaction among a network of related activities (Wilson, 2008).

2.8.1. The Origin and Development of Activity Theory

Activity theory emerged as an outgrowth of the sociocultural perspective in Russian/Soviet psychology of the 1920s and 1930s. The origin of activity theory was to study human consciousness which form during activity and can explain the nature of human behavior consisting of activities (Wilson, 2008). The triadic structure of the human activity (i.e., subject, tools, and object) was influenced by Vygotsky’s work. A subject can be a person or a group of persons participating in an activity (Nardi, 1996). Object refers to an objective held by the subject motivating an activity. Subjects have their own needs and thus must carry out activities, that is, interact with objects to meet the needs. Object is perceived as something that can meet a need of the subject. Activity, the foundational concept of activity theory, then refers to a special type of relationship between the subject and the object which mediated by tools. Due to the
concentration on consciousness, Vygotsky (1981) introduced the notion of abstract tools, such as language, signs, and symbols, by making analogy to conventional technical tools. Vygotsky also proposed the concepts of internalization and externalization which refer to the processes of mutual transformations between internal and external components of an activity. Internalization refers to an individual’s thought activity to reason and reconstruct external objects or acquire new abilities, such as one’s activity of learning community policies and rules (Kaptelinin, 1996). In contrast, externalization refers to the process that people manifest, verify, and correct their mental models through external actions, such as one’s activity of formulating new community policies and rules.

Leont’ev changed his focus on Activity Theory from human consciousness to object-oriented activity and tools (Wilson, 2008) by introducing the concept of division of labor to the theory and developing the hierarchical structure of human activity distinguishing among activity, actions, and operations. The top level of the structure is activity itself, which is oriented towards a motive and can be further divided into actions dependent on the division of labor. Actions are conscious processes directed at goals which must be undertaken to fulfill the motive and further implemented through lower-level units called operations. Operations are routine processes providing an adjustment of an action to the ongoing situation. With practice, it will require little conscious attention to carry out the operations, which may have become routinized or habituated behaviors. Leont’ev also expanded the concept of tools to include both abstract and physical tools.

While Leontiev pointed out that activities can be carried out not only by individuals but by social entities (collective subjects), the model he proposed did not explore the structure and development of collective activities, ignoring the interaction between the subject and the activity.
environment. To fill this gap, Engeström (1987) proposed a model of collective activity which included other concepts (e.g., community, rules, division of labor, contradictions) that were pertinent to work contexts. Engeström’s model is a two-step extension of Leontiev’s original concept of activity in which activity is understood as subject-object interaction. The most significant revision was adding a third element, community, which resulted in a structure comprising a three-way interaction between subject, object, and community. Second, Engeström’s model suggests that each of the three particular interactions within the structure is mediated by a special type of means. Concrete mediational means for these interactions, according to Engeström, are: (1) tools/instruments for the subject-object interaction, (2) rules for the subject-community interaction, and (3) division of labor for the community-object interaction. By community is meant those who share the same object; by tools/instruments is meant the artifacts, signs, and means that mediate the subject and object; by rules is meant a set of agreed conventions and policies covering what it means to be a member of that community; and by division of labor is meant the primary means of classifying the labor in a workplace. In addition, this model includes the outcome of the activity system as a whole: a transformation of the object produced by the activity into an intended result. Engeström’s model indicates that his focus on Activity Theory transformed from human consciousness and individual activity to community and places an emphasis on identifying the interaction among a network of related activities (Wilson, 2008).

2.8.2. Principles of Activity Theory

Kaptelinin and Nardi (2006) identified five principles which elaborate activity theory into more specific notions, claims, and arguments.

The first principle is object-orientatedness, which states all human activities are directed toward
their objects and are differentiated from one another by their objects. Objects motivate and direct activities, around them activities are coordinated, and in them activities are solidified when the activities are complete. Analysis of objects is therefore a necessary requirement for understanding human activities, both individual and collective ones.

The second principle is the hierarchical structure of activity, with activities at the highest level of the hierarchy, actions at the intermediate level, and operations at the lowest level (Kaptelinin, 1996). Activities, actions, and operations differ in their process: activities are oriented to specific motives that are impelling by themselves, actions are directed to particular goals that are auxiliary, and operations are condition-dependent and the process of which is automatized. The hierarchical activity system is dynamic and activities, actions, and operations are interchangeable. Over time, activities may become actions and operations. Actions can become operations through automatization, while operations can become actions through de-automatization. Kaptelinin (1996) pointed out that when motives, goals, and conditions are frustrated, they differ in the predictability of human behavior and emotion. When the conditions are changed, people may adapt to the new conditions without realizing the changes. Similarly, when the goals are frustrated, people may set new goals without much negative emotion. However, if the motives are upset, people may become distressed, and their behavior may turn to be unpredictable. The process of transforming an object into an outcome involves this hierarchical structure of activity.

The third principle is internalization-externalization, depicting that people’s consciousness of the external world is formed through internalizing their external activities (Wilson, 2008). Language is one of the techniques that people employ to internalize their external experience.
The fourth principle is mediation stating that tools, either physical (e.g., hammers, computers) or abstract (e.g., language, symbols), mediate human activities (Kaptelinin, 1996). As a source of socialization carrying specific cultures and social experience, tools shape the way that people act. Wilson (2008) claimed that rules, norms, and division of labor in Engeström’s structural representation of human activity could be considered as tools mediating between the subject and object.

The last principle is development. Activities, including each component of an activity system, are not static, but under continuous development (Kaptelinin, 1996). Thus Activity theory requires that activities always be analyzed in the context of development. The concept of contradiction is closely related to this principle. Contradictions refer to any historically accumulated tensions or inabilities within or between activity systems, playing a central role in changing and developing activities (Engeström, 1987). It is acknowledged that contradictions will inevitably occur within or between activities (Engeström, 1993) in any complex situation and that, far from being a problem to solve, contradictions can be a source of learning, growth and innovation. To understand the development of a specific activity system, one may conduct historical and empirical analyses of the system to trace the contradictions that have occurred (Engeström, 1987). Engeström (1987) classified contradictions into four categories: primary contradictions are inner contradictions of each of the components of an activity system, secondary contradictions are those that arise between the components of an activity system, tertiary contradictions happen between different developmental phrases of the activity, and quaternary contradictions appear between an activity system and other activity systems involved in the production of a joint outcome.
2.8.3. Strengths and Weaknesses

The strength of Activity Theory lies in its ability to enable deconstructing an activity into components (e.g., subject, object, tools, rules), analyzing it in different levels (collective and individual), and reducing it to a hierarchical structure (i.e., activity-actions-operations), as well as its universalness in facilitating the communication and knowledge transfer between different research communities. Activity Theory can be used as a conceptual framework, providing researchers with concepts and structure to organize, analyze, re-examine, and give new insight into their data. As a methodological framework, Activity Theory can be used to develop research instruments and formulate research questions, guiding methodological decisions. As a meta-theory, it can help develop theoretical frameworks and models.

Due to its origin, there are terminology problems of translating concepts of Activity Theory from Russian to English, such as activity and object (Kuutti, 1996). Wilson (2008) emphasized that the concept of activity in Marxist is closely related to the concepts of “practice” and “labor”. Activity in Russian carries the meaning of human behavior (or practices) transforming an object into an outcome, while its English equivalent does not convey. The vocabulary problems also pose challenges for using Activity Theory to communicate, analyze, and explain data. For example, Nardi (1996) comprehended the concept of object as an objective held by a subject motivating an activity. Engeström (1990) considered object as the raw material or problem space upon which the activity acts. Turner, Turner, and Horton (1999) perceived it as an objectified motive, combining the meanings of activity motive and the object upon which the activity acts.

2.8.4. Previous Applications

Activity theory (AT) has been widely used and expanded in the (Human-computer interaction) HCI and Computer-supported cooperative work (CSCW) research since its introduction to these
field in the late 1980s (Bødker, 1990). In general, contributions of the AT to these fields have been of the following three types: (1) theoretical re-framing of some of the most basic concepts in certain fields, (2) providing conceptual tools for design and evaluation, and (3) serving as a theoretical lens in empirical studies (Kaptelinin & Nardi, 2012). Research related to knowledge curation in online communities falls into the last type, using the concepts in AT to analyze empirical evidence obtained in the studies. Bryant et al. (2005) interviewed expert contributors to Wikipedia and used Engeström’s activity system model as a conceptual tool for understanding the development of novices into “Wikipedians.” The authors showed that the development can be described in terms of the transformation of subjects, transformation of tool use (e.g., the use of editing tools and watch-lists), as well as transformation of subjects’ perceptions of community, rules, and division of labor. (Hasan & Pfaff, 2012) collected qualitative data through semi-structured interviews and observations and used the concepts of contradiction in Engeström’s activity system model to explore reasons why some organizations are more successful than others in collaboratively building and sharing knowledge via corporate wikis. Malone and Stevens (2013) measured the level of activity in ontology building projects, with the goal of both providing an analytical view over the collaboration process and making predictions on their future directions. They analyzed several factors, ranging from basic change operations (add/delete/update) or frequency of releases to person-centric participation metrics, to lay the foundation of an overarching activity metric that could be adopted as an assessment criterion for community ontology development. From a quantitative perspective, the results of their study measured the usefulness of these factors, while from a qualitative perspective, they shown a constant trend in collaborative development of ontologies across multiple communities. Based on data from participant observation, documentary analyses, and semi-structured interviews, Rozas
used AT as a lens with which to analyze the motivations to contribute and mechanisms employed in the coordination of the development of the Free open source software Drupal. The author identified two types of activities perceived as contributions in the Drupal community, i.e., object-oriented activities including providing source code, documentation, and translations, etc.; and community-oriented activities including usage and support, evangelization, training and mentoring, organization and participation in Face-to-Face events, etc. Different types of activities help to foster collaboration in the community, but the degree of effectiveness varies by members’ roles (new members, experienced members, administrators, etc.). Some activities can be understood as affective labor, especially those related to organization and participation in Face-to-Face events, and play a relevant role in the sustainability of the community.

2.9. Collective Effort Model

Collective Effort Model (CEM) was proposed and developed by Karau and Williams (1993) as a meta-theory of social loafing, which calls out factors that influence people’s motivation to contribute to groups. CEM is based on Vroom (1982)’s expectancy-value account of motivation, which suggests that one’s motivation for a given effort depends on how well that effort translates into performance, what outcomes the expected level of performance is likely to lead to, and how much those outcomes are valued. CEM posits that people consider these factors both from an individual and a group perspective. Further, in the case of groups, people consider whether their effort will make a contribution to the group’s performance and whether that contribution will matter to the group’s overall performance.

2.9.1. The Origin of Collective Effort Model

Based on the rope pulling experiment, Ringelmann (1913) found that as group size increased, there was a marked decrease in the total force exerted over what would have been expected on
the basis of individuals’ performance. This raises the possibility that working in a group on a
task might be demotivating for the individual members. Ringlemann’s findings were replicated
in Latané, Williams, and Harkins (1979) by demonstrating that a substantial portion of the
performance decrease in groups was caused by motivation loss rather than coordination loss.
They also coined the term social loafing for the demotivating effects of working in groups and
described it as a type of social disease. Social loafing has been found for a wide variety of tasks
including physical tasks, cognitive tasks, evaluation tasks, and creative tasks, as well as cross
most subject populations. Several researchers proposed theories of social loafing, some of the
most prominent have been included in Karau and Williams (1993) meta-analysis: (1) Social
Impact Theory, (2) Arousal Reduction, (3) Evaluation Potential, (4) Dispensability of Effort, (5)
Self-Efficacy.
Karau and Williams (1993) argued although support has been found for those five theories, the
most significant limitation is that each offers explanations and makes predictions about social
loafing within a restricted domain. They asserted this field lacks a single theoretical framework
that can be applied to analyze social loafing under different conditions, and thus adopted a more
general theory of motivation (Vroom, 1982) and proposed an integrative model of individual
effort on group tasks, the collective effort model (ECM). They argued social loafing occurs
because the contingency between one’s effort and valued outcome is, in most cases, weaker
when working collectively than when working coactively or alone. Paramount to their theory is
the idea that when working in a group, there are many factors other than individual effort than
can determine the performance on a given task. The ECM specifies that an individual will exert
effort on a collective task to the extent that his/her efforts will be instrumental in obtaining
valued outcomes. However, if an individual’s performance is not perceived to be linked to the
group performance, or if the potential outcomes are not valued by the individual, individuals will not work hard. In addition to these factors, expectancy, or the degree to which levels of effort are believed to be associated with high levels of performance, is also considered to influence motivation of exert effort in a group.

2.9.2. Components of CEM

Like traditional expectancy-value model of effort, the CEM assume that individuals attempt to maximize the expected utility of their actions. In Vroom’s original model there are three main concepts, as follows: (1) expectancy, the degree to which high levels of effort are expected to lead to high levels of performance, (2) instrumentality, the degree to which performance is perceived as instrumental in obtaining an outcome, and (3) valence of the outcome, i.e., the degree to which the outcome is viewed as desirable. CEM expands on Vroom’s logic by identifying specific concepts predictive of social loafing in group work, as below:

- Individual effort: The total work an individual has done for a collective task;
- Individual performance: How well an individual function;
- Individual outcome: The result or consequence following the individual’s work;
- Value of individual outcome: The degree to which the individual outcome is viewed as desirable;
- Group performance: How well a group functions;
- Contribution to group performance: The degree to which individual performance contributes to group performance;
- Group outcome: The result or consequence following the group’s work;
- Value of group outcome: The degree to which the group outcome is viewed as desirable;
• Individual motivation: eagerness and willingness of an individual to participate in a collective work.

Main propositions of ECM include the following:

1. Individual’s motivations to contribute to a collective task/group work are positively correlated to the degree that the individual’s performance is perceived to be linked to group performance (believing that their contributions are identifiable).

2. Individual’s motivations to contribute to a collective task/group work are positively correlated to the extent to which the group performance will be instrumental in obtaining a valued group outcome (believing that the group they are working with is productive).

3. Individual’s motivations contribute to a collective task that is positively correlated to an individual’s perceived value of the outcome of the task (liking the output of the group they are working with).

2.9.3. Implications

The CEM generates several specific predictions regarding individual motivation in groups. It suggests individuals will work harder on a collective task when they expect their effort to be instrumental in obtaining valued outcomes. Therefore, social loafing in a group or community can be reduced when individuals (1) believe that their collective performance can be evaluated by others, (2) work in smaller rather than large groups, (3) perceive that their contributions to the collective product are unique, rather than redundant with the inputs of other group members, (4) are provided a standard with which to compare their group’s performance, (5) work on tasks that are either intrinsically interesting, meaningful to them, (6) work with respected people or in a situation that activate a salient group identity, (7) have a dispositional tendency to view favorable collective outcomes as valuable and important, and (8) have feelings of high self-efficacy and
high collective efficacy for their group on the task (Karau & Williams, 2001). Because the CEM incorporates elements from a variety of prior theories in areas such as social identity, general human motivation, and work motivation, it represents an integrative model that should fit a wide variety of groups. Those factors identified above should not only be used for predicting and interpreting individuals’ contribution motivations but also suggest clear strategies for enhancing group members’ efforts on collective tasks in either organizational work groups or online peer production communities.

2.9.4. Strengths and Weaknesses

Although the notion that expectancy-value models can be used to shed light on individual motivation in group contexts is not entirely new, CEM is unique in specifying contingencies between effort and outcomes that are unique to collective context, and in using group-level social comparison and self-evaluation theories to identify which specific factor should influence individual motivation within groups. This combination allows for the identification for a range of threats to collective motivations in a manner that is not restricted to mere task performance outcomes (Karau & Williams, 2001). The strengths of CEM lie in its applicability to groups the instructiveness to identify specific implications to motivate high-quality contributions across various settings. CEM is a useful tool for performing diagnosis: researchers can apply it to identify tools and resources for keeping group members motivated, by analyzing potential disconnection between elements in the model. The weakness of CEM probably also lies in its degree of flexibility. The model has been conceptualized as having too wide structure thus hamper its possible success in identifying the real problem in community design which reduces people’s contribution motivation.
2.9.5. Previous Applications

The CEM has been considered as a rich tool for analyzing designs regarding the motivating contributions by CSCW communities. Broadly, the model suggests that motivation increases when connections among those nine concepts/elements in the model strengthen. For example, giving people a tool that reduces the effort required to add a FAQ entry should increase their motivation to do so, all other things being equal. By calling out these connections, the model can help designers scrutinize motivation and suggest strategies for increasing it. Specific to knowledge curation in online communities, CEM is mainly used to identify gaps in design, with the aim to increase motivation, and consequently, participation in online communities, thus generating design innovations that are not obvious from design practice (Ling et al., 2005). This explains why certain designs are able to increase high-quality contributions (Cosley et al., 2005, 2006; Ludford, Cosley, Frankowski, & Terveen, 2004). Ling et al. (2005) conducted four field experiments involving members of an online movie recommendation community to test design principles derived from CEM, by giving different explanations for the value of participants’ contributions in each of the experiments. As predicted by CEM, individuals contributed more when they were reminded of their uniqueness and when they were given specific and challenging goals. Cosley et al. (2005) used the CEM to predict how peer and expert editorial oversight affect members’ contributions to movie recommendations. In this case, CEM predicted (1) high-quality posters will be more motivated if they know they will have more readers, (2) helping people achieve better performance for a given effort will motivate them to contribute, (3) oversight is important because it reassures high-quality contributors that their contributions matter, which had been proven in a later field experiment with 87 contributors. In their later work, (Cosley et al. (2006) used CEM to shape their study about intelligent task routing. The goal of their study
was to increase the frequency that members corrected information in the MovieLens web site’s database by matching members with movies they would edit. The study picked up four strategies for choosing movies based on the collective effort model to conduct field experiments, namely: choosing random movies, choosing movies the person was predicted to like, choosing movies that were missing the most information in the database, and choosing movies the person had previously rated. The results show that choosing rarely rated movies and choosing movies the person had previously rated were the most effective strategies for convincing people to contribute, since these two strategies increase the value of participants’ contributions (editing rarely rated movies matters more) and reducing the effort of contributing (editing known movies is an easier task).
CHAPTER 3

METHOD

This chapter begins with presenting the research purpose and questions of this study. This chapter continues with presenting a research plan with details about how content analysis, social network analysis, and qualitative semi-structured interviews were conducted and how the data were analyzed. This chapter also covers discussions of ethical issues, quality control, and data management of the study.

3.1. Research Questions

Guided by Activity Theory, the purpose of this exploratory study is to gain a better understanding of the community design and management work of social Q&A communities at their startup phase: how they define their communities’ objectives and scopes; how they define community success; how they recruit, select, and keep their community members; how they motivate members’ contribution, decide the community structures, and maintain the quality of community outputs.

The following four research questions satisfy the purpose of the proposed study introduced in Chapter 1:

1. What are some of the activities in social Q&A communities at the startup stage? What are their objects?

   1.1. Who are the subjects of those activities?

   1.2. What are the motivations for engaging in these activities?

   1.3. What are some of the norms and rules regulating these activities?

   1.4. What is the division of labor within these activities?

   1.5. What are some of the tools used in these activities?
1.6. What are some of the contradictions within and between these activities and how these contradictions have been solved?

1.7. What are some of the skills needed to participate in the community?

2. How does Stack Exchange define the success of a Q&A community?

2.1. What criteria are used by Stack Exchange to evaluate if a Q&A community has succeeded through each stage? Do the criteria shape and if so, how do they shape the community dynamics at the startup stage?

2.2. What do members consider as indicators to assess how successful a Q&A community is?

2.3. What do members consider as criteria and/or measures of high quality questions and answers?

3.2. Research Setting: Stack Exchange

Stack Exchange³ is a network of more than 170 Q&A communities including Stack Overflow, the preeminent Q&A sites for programmers. Area 51⁴ is the Stack Exchange network staging zone where groups of experts come together to build new Q&A sites that work just like Stack Overflow. Anyone can propose a new Q&A site (called a proposal) in Area 51, but reaching out to other experts and defining the type of questions that are wanted is a community-driven process.

A proposed Q&A site need to go through four phases before it becomes a full member of the Stack Exchange network: Definition, Commitment, Private Beta, and Public Beta. In every phase a proposed Q&A site should feature activities addressing different perspectives in

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³ http://stackexchange.com/
⁴ http://area51.stackexchange.com/
community building, and criteria and measures used to evaluate if the site is qualified to move to the next stage also vary among phases.

During the “Definition” phase of a proposed Q&A site, anyone who feels interested in the site can follow it. The centered activity in this phase is to identify the scope of the site, by letting its early members to propose example questions and vote whether or not those questions are good for the site. Questions can be up-voted if a member thinks they will be interesting, down-voted if s/he thinks they won’t be, or closed if s/he thinks they are a poor fit for the community. A site is considered as “defined” and allowed to move to the next phase with 60 followers and at least 40 questions with a score of 10 or more. Discussions related to any community building issues are also encouraged but not counted as a check point.

When a proposed site enters the “Commitment” phase, a petition for the site’s creation is presented. Followers in definition phase will received notifications and asked to digitally “sign” the proposal with their full names (will not show publically) and their professionalisms of the topic of the site to help assure that site will have an active community in those critical early days. They are also encouraged to share the petition via social media to bring new members to the site.

To ensure the commitment is taken seriously, a user can only commit to three sites at any one time. A site is allowed to move to next phase when it reaches 100% commitment⁵.

A private beta will be launched once a proposed site has reached 100% commitment. During the private beta phase, the site will be run in a regular mode as any other Q&A site in Stack Exchange, but only the people who committed to it can participate. At this stage those committers are not allowed to invite any outsider to join the site or share the content via social media. A Meta site (similar to the discussion space in definition phase), as a space for discussion

⁵ http://meta.stackexchange.com/questions/53650/area-51-commit-percent/53733#53733
about the beta site itself - what questions are appropriate, what tags should be used, or other promoting and governance issues - will also be launched from this stage. The private beta generally lasts one to two weeks. If the site is popular with questions and its initial scope established, it will turn into a public beta that everyone can participate. During the public beta phase, members are strongly encouraged to invite friends and spread the site via social media. A public beta remains in beta for at least 90 days and has at least 10 users with more than 2,000 reputation points and 5 users with more than 3,000 reputation points to build up a critical mass of users, questions, and participation. However, meeting those three hard limits does not guarantee a public beta be launched (graduated). There are no published measures for a site in beta phase (both for a private beta moving to public beta and for a public beta moving to launched status). Stack Exchange offers some “vital signs” for members to self-evaluate the health of a beta site, including: question per day, percentage of answered questions, total users, avid users, answer ratio, visits per day. Stack Exchange assigns site health status (Excellent, OK, or Needs work) for each vital sign as references, but no hard limit for any sign is set to guarantee a site can graduate from beta to launched (receiving “Excellent” in each item does not necessarily lead to graduating). A beta site can remain in beta as long as it needs (the oldest beta has been in beta status for 1802 days).

To address the research questions, this study will examine two social Q&A sites from Area 51 – one successful and one unsuccessful. Data dumps for each site, including both the main site data (all topic specific question-answering threads) and the meta site data (all site managing discussion threads), have been published by Stack Exchange. The unsuccessful site, called

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6 http://meta.stackexchange.com/questions/76338/what-are-the-success-criteria-for-an-area-51-beta-site
7 http://area51.stackexchange.com/proposals/5220/board-and-card-games
Economics, successfully passed the definition, commitment, and private beta phases, but failed to be launched and was closed by Stack Exchange after staying in the public beta phase for 206 days. The successful site, called Mathematics passed through all four phases and was launched (considered as graduated from Area 51) in October 2010. These two sites were chosen for comparison based on the following criteria (1) they were proposed on the same day (6/3/2010); (2) the potential user groups/community sizes for both Economics and Mathematics are at the same order of magnitude (the researchers use the numbers of degrees conferred by postsecondary institutions each year to estimate the size of each science community).

3.3. Research Design

This dissertation study employed a mixed methods research design, using qualitative and quantitative methods together to combine their strengths and minimize their weaknesses, to improve validity and reliability, and to obtain a fuller understanding of the difference in successful and unsuccessful online peer production communities and the success factors at community’s startup stage. The research design is an exploratory sequential design: multiple methods are used within one study; qualitative and quantitative data are collected and integrated in sequence; a greater emphasis is placed on the qualitative data.

The researcher first performed content analysis of the archival data from Mathematics Stack Exchange (successful one) and Economics Stack Exchange (failed one) between 2010 and 2012 to gain an initial understanding of the communities’ work and relationships. The researcher then conducted social network analysis to examine the network structures and user interaction patterns of two sites. Semi-structured interviews were conducted with key informants from those two communities—including community administrators, active contributors, new users—to
answer the questions which cannot be answered directly and/or the follow-up questions suggested by content analysis and social network analysis.

These three methods were selected based on the purpose of the proposed research, community setting, and research questions discussed above. Content analysis were used to answer all the research questions except those perceptual and psychological questions (e.g. motivations). Social network analysis was used to understand the factors contributing to the success/failure of groups within these networks. Semi-structured interviews were used to address all research questions, especially to collect data that is not available from content analysis.

3.3.1. Theoretical Framework

This dissertation research draw on a synthesized theoretical framework consisting of two theories, discussed and developed with more details in Chapter 2. The primary theory is Engeström (1990)’s Activity Theory. Engeström’s Activity Theory is a two-step extension of Leont’ev (1978)’s original concept of activity in which activity is understood as subject-object interaction, with an emphasis of the social aspect of activities. The significant revision of adding the community concept resulted in a structure comprising a three-way interaction between subject, object, and community. The relationship between subject and object is mediated by tools; the relationship between subject and community is mediated by rules; and the relationship between object and community is mediated by division of labor. The concepts/elements included in Engeström’s Activity Theory are:

- Subject: a person or a group of persons participating in an activity;
- Object: an objective held by the subject motivating and directing an activity;
- Community: those who share the same object and can be defined in different levels;
- Tools: artifacts, signs, and means that mediate the subject and object;
• Rules: a set of agreed conventions and policies covering what it means to be a member of that community;
• Division of labor: the primary means of classifying the labor in a community;
• Outcome: the transformation of the object produced by the activity into an intended result.

Engeström’s Activity Theory was used as a methodological framework to help formulate some of the research questions (RQ1), including exploring activities and actions around Q&A community creation and development, examining the division of labor among these activities, identifying the community norms and rules regulating these activities, examining the tools mediating those activities, and understanding the contradictions positively and negatively affecting these activities. Research questions that Activity Theory helped to formulate also determined the qualitative research methods for this study: content analysis, social network analysis, and semi-structured interviews.

The second theory used in this study was the Collective Effort Model developed by Karau and Williams (1993). Collective Effort Model expands Vroom (1982)’s expectancy-value account of motivation by identifying specific concepts predictive of social loafing in group work, including:

• Individual effort: The total work an individual has done for a collective task;
• Individual performance: How well an individual function;
• Individual outcome: The result or consequence following the individual’s work;
• Value of individual outcome: The degree to which the individual outcome is viewed as desirable;
• Group performance: How well a group functions;
• Contribution to group performance: The degree to which individual performance contributes to group performance;
• Group outcome: The result or consequence following the group’s work;
• Value of group outcome: The degree to which the group outcome is viewed as desirable;
• Individual motivation: eagerness and willingness of an individual to participate in a collective work.

Broadly, Collective Effort Model suggests that contribution motivation increases when connections among those nine concepts/elements in the model strengthen. This model has been considered as a rich tool for analyzing designs regarding the motivating contributions, control content quality, and other community supporting works.

3.3.2. Case Study Approach

This study took a case study approach, where a detailed and intensive analysis of individual cases—Economics Stack Exchange and Mathematics Stack Exchange—was performed. Case study is defined as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 2013). Case studies often focus on the cycle of research methods which inform each other through a longer, more detailed research process than using a single exploratory method. A case study approach fosters multiple opportunities to revisit and reanalyze data collected earlier in the study, revise the research design as new facets and factors emerge, and combine multiple methods and data sources into a holistic description of each case. The research design used here, employing two qualitative and one quantitative method in a cycle, followed this approach.
The uniqueness, complexity, and embeddedness of community development strategies and processes within a specific context (Q&A system) point out the use of case study as an appropriate methodology. Understanding how and why some Q&A communities succeed while some failed, and the successful factors impacting community success, is a complex set of “how” and “why” questions are well suited for case study analysis (Yin, 2013). As also documented by Yin (2013), a case study design is optimal in this instance as the researcher wants to cover contextual conditions—believing that they might be highly pertinent to the phenomenon of study. Yin also advocated for the use of the case study methodology to explain “real life intervention too complex for a survey methodology”. The research questions proposed in this study meet all criteria for case study analysis. The community building strategies and processes and the community context are unable to be separated. For example, community members may use certain strategies to meet passing criteria set by Stack Exchange. Also the community development issues are “technically distinctive” requiring the utilization of many sources of data to fully address.

Yin (2013) breaks the process of conducting a case study into five phases. First, one must determine the research questions to be asked; these were included in section 3.1 above. Second, one must identify what Yin calls the “propositions,” statements “direct[ing] attention to something that should be examined within the scope of study” (p. 22). The theoretical framework developed earlier (see section 2.8) and the purpose of this research as stated in Chapter 1 provide this necessary focus from a conceptual perspective. The operationalization of this focus is discussed for each method in sections 3.4.2, 3.5.2, and 3.6.6. Third, Yin says one must determine the unit of analysis, based on the research questions. In this study, the overall units of analysis are the two social Q&A communities under consideration, Economics Stack Exchange and
Mathematics Stack Exchange; other units of interest include subgroups and individual users. The specific unit of analysis for each method of data collection is discussed in sections 3.4.1, 3.5.2, and 3.6.1. Fourth, one must connect “data to [theoretical] propositions,” matching patterns with theories (p. 26). Using the theoretical framework developed in section 2.8 in data analysis (see Chapter 4) provides for this matching process. For the final step, Yin says one must determine “the criteria for interpreting [the] findings” (p. 27), suggesting measuring the quality of the design against four criteria which include construct validity, internal validity, external validity, and reliability. This has been discussed in section 3.7.1.

The type of case study used in this dissertation work was a comparative, multiple case. At the highest level, this case study focused on Mathematics Stack Exchange and Economics Stack Exchange, with multiple units of analysis considered in each method, what Yin (2013) called embedded design, at lower levels. Comparative case studies “emphasize comparison within and across contexts” and “involve the analysis and synthesis of the similarities, differences and patterns across two or more cases that share a common focus or goal” (Goodrick, 2014, p.87). Goodrick (2014) also suggested comparative case studies are suitable in the following circumstances: (1) When ‘how’ and ‘why’ questions are being posed about the processes or outcomes of an intervention; (2) When there is an opportunity for iterative data collection and analysis over the time frame of the intervention; (3) When an understanding of the context is seen as being important in understanding the success or failure of the intervention; (4) When experimental and/or quasi-experimental designs are unfeasible for practical or ethical reasons.

This study meets all of these criteria. Examining social process within Stack Exchange Q&A system and producing more generalizable knowledge about – how and why particular O&A community development process or strategies work or fail to work. Since Stack Exchange Q&A
system has its unique policies, social norms, member composition, the community building strategies and processes and the community context cannot be separated. Given the focus on generating a good understanding of the community development and the community context, methods including content analysis, social network analysis, and semi-structured interviews are employed in this study. Those three methods were conducted in sequence (content analysis—social network analysis—semi-structured interviews; see Figure 3.2) since each method built on the methods before it.

Details about what data has been collected and how the data is analyzed in each method are discussed in the following sections of this chapter. Findings of each method are aggregated mainly by two strategies: aggregating results from analyses of separate data components and aggregating one form of data to inform the design or analysis of another. Findings of content analysis and social network analysis were used to help design interview questions and select key informants if possible. Findings of those research questions that can be addressed using more than one research methods (e.g. activities, division of labor, success criteria and factors, etc.) were compared to see if those findings confirm each other, offer complementary information on the same research question, or appear to contradict each other.

3.3.3. Mixed Methods Research

This case study used a mixed methods design, combing content analysis, social network analysis, and semi-structured interviews. Definitions of mixed methods research vary but core characteristics can be identified, which (Creswell & Plano Clark, 2011, p. 5) summarize as: (1) collection and analysis both qualitative and quantitative data; (2) integration of the two forms of data in sequence or in an embedded design; (3) combining methods within a single study or multiple phases of a larger study; (4) framing the data collection and analysis within
philosophical, epistemological, and theoretical lenses; (5) conducting the study according to other specific criteria. This study meets all of these criteria. Qualitative and quantitative data are collected and integrated in sequence; multiple methods are used within this one study while qualitative data is prioritized; and the study is based on the theory and model explained in Chapter 2.

Creswell and Plano Clark (2011) encompassed multiple viewpoints and potential about how to choose a mixed methods design (pp. 53-104). They considered six prototypical designs: (1) convergent parallel; (2) explanatory sequential; (3) exploratory sequential; (4) embedded; (5) transformative; and (6) multiphase. The research design for this dissertation study is an exploratory sequential design. The selection of this design and methods used is based on the research purpose discussed in Chapter 1, the research questions introduced in section 3.1, and the research setting explained in section 3.2. The methods used are:

- **Content analysis** of community activity logs and community developing discussion threads in Math Stack Exchange and Economics Stack Exchange;
- **Social network analysis** of asker-replier graphs of Math Stack Exchange and Economics Stack Exchange;
- Semi-structured *interviews* with core members of in Math Stack Exchange and Economics Stack Exchange.

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**Figure 3.1. Research Process**
<table>
<thead>
<tr>
<th>Research Question</th>
<th>Theory</th>
<th>Data Collection Methods</th>
<th>Interview Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are some of the activities in social Q&amp;A communities at the startup stage? What are their objects?</td>
<td>Activity Theory</td>
<td>content analysis semi-structured interview</td>
<td>#6, #8, #15</td>
</tr>
<tr>
<td>1.1. Who are the subjects of those activities?</td>
<td>AT: Subject</td>
<td>semi-structured interview</td>
<td>#1, #4</td>
</tr>
<tr>
<td>1.2. What are the motivations for engaging in these activities?</td>
<td>CEM</td>
<td>semi-structured interview</td>
<td>#6</td>
</tr>
<tr>
<td>1.3. What are some of the norms and rules regulating these activities?</td>
<td>AT: Rules</td>
<td>content analysis semi-structured interview</td>
<td>#11</td>
</tr>
<tr>
<td>1.4. What is the division of labor within these activities?</td>
<td>AT: Division of Labor</td>
<td>content analysis social network analysis semi-structured interview</td>
<td>#12</td>
</tr>
<tr>
<td>1.5. What are some of the tools used in these activities?</td>
<td>AT: Tools</td>
<td>content analysis semi-structured interview</td>
<td>#10</td>
</tr>
<tr>
<td>1.6. What are some of the contradictions within and between these activities and how these contradictions have been solved?</td>
<td>AT: Contradictions</td>
<td>semi-structured interview</td>
<td>#14, #19</td>
</tr>
<tr>
<td>1.7. What are some of the skills needed to participate in the community?</td>
<td>AT: Division of Labor</td>
<td>semi-structured interview</td>
<td>#13</td>
</tr>
<tr>
<td>2. How does Stack Exchange define the success of a Q&amp;A community?</td>
<td></td>
<td>content analysis semi-structured interviews</td>
<td>#16, #17</td>
</tr>
<tr>
<td>2.1. What criteria are used by Stack Exchange to evaluate if a Q&amp;A community has succeeded through each stage? Do the criteria shape and if so, how do they shape the community dynamics at the startup stage?</td>
<td>CEM</td>
<td>content analysis semi-structured interview</td>
<td>#17</td>
</tr>
<tr>
<td>2.2. What do members consider as indicators to assess how successful a Q&amp;A community is?</td>
<td></td>
<td>semi-structured interview social-network analysis</td>
<td>#16, #18</td>
</tr>
<tr>
<td>2.3. What do members consider as criteria and/or measures of high quality questions and answers?</td>
<td></td>
<td>semi-structured interview</td>
<td>#20, #21</td>
</tr>
</tbody>
</table>
The holistic combination of these methods, interrelated in a multiphase design, has allowed for exploratory and descriptive research on social Q&A community developing process and strategies incorporating the strengths of quantitative and qualitative methods and the viewpoints of multiple perspectives. A sequential, multiphase research design is employed because each method built on the methods before it. The design of the interview instrument is influenced by the literature and theories and by discovery during the content analysis and social network analysis phase.

Several ad hoc techniques proposed by Miles and Huberman (1994) have been used for meaning condensation and interpretation, including noting patterns and themes, clustering, counting, making comparisons, building a logical chain of evidence, and making theoretical coherence. Noting patterns and themes and clustering help to see “what goes with what”. The former one is achieved by maintaining a consistent focus on the same and recurring phenomena throughout all three phases and the latter one is achieved by grouping and then conceptualizing phenomena that have similar patterns or characteristics. Counting and Making Comparisons are used to sharpen understanding. A theme or a pattern is identified because it happens a number of times and consistently happens in a specific way. Which particular pattern happens there more often, which matter more than others, which go together, are the sources of saying that something is significant or recurrent; these are achieved by making counts and comparisons. Building a logical chain of evidence and making theoretical coherence are used to assemble a coherent understanding of data. The methods used in this study link together and inform each other to establish chain of evidence. Data from content analysis helps inform the interview protocol, while the social network analysis data help select interview participants. Data from all three
methods is tied together in the overall findings and conclusions from the study. Activity Theory is used as the theoretical framework to form the themes in the data analysis stages.

3.4. Content Analysis

Content analysis is a technique used to make replicable and valid inferences in the textual, pictorial, symbolic, and communication data (Krippendorff, 2004). Early forms of content analysis required objectivity and highly systematic procedures; The form of content analysis used in this study considers the meaning and understanding of content to “emerge in the process of a researcher analyzing a text relative to a particular context” (Krippendorff, 2004, p. 19), a subjective and less rigid approach.

There are at least three categories of content analysis, which Ahuvia (2001) labels traditional, interpretive, and reception-based; other researchers (Babbie, 2012, p. 325; Holsti, 1969, pp. 12-14) break content analysis into latent (subjective and qualitative) and manifest (objective and quantitative) categories of analysis. Early content analysis was purely objective and generated quantitative summaries and enumerations of manifest content, but qualitative and latent analysis have found greater acceptance over time (Ahuvia, 2001; Holsti, 1969; Krippendorff, 2004). This study used the interpretive approach and focused coding on the latent content—the underlying meaning—of the data gathered.

3.4.1. Population and Sampling

The unit of analysis chosen for the content analysis is the question-answering threads on the main site and discussion threads on the meta site, each of which may contain multiple posts. Analysis of question-answering and discussion threads aims at uncovering community building actions and community building strategies at community’s startup stage defined by Stack Exchange.
The data used for content analysis is extracted from data dump published by Stack Exchange network. The Economics site spans 30 weeks, from October 2011 when the site entered private beta, to May 2012 when the site was closed. The data used for the Mathematics site spans from July 2010 when the site entered private beta, to March 2015 when the published data ends. Since the Mathematics site graduated from public beta at the end of Week 14, the study used the Mathematics site data from the first 16 weeks for comparison to Economics site. The final dataset used in this study included: (1) 166 site managing discussion threads from the Economics meta site, (2) 3,284 post history records (identified by PostHistoryTypeId) of 1,007 question-answer threads from the Economics main site, (3) 966 site managing discussion threads from the Mathematics meta site, (4) 21,684 post history records of 8,559 question-answer threads from the Mathematics main site.

3.4.2. Data Analysis

NVivo 11 is used to perform content analysis. Each thread is examined and codes are assigned based on its latent meaning and interpretation. The researcher performs content analysis with open coding of 166 discussion threads from the Economics meta site. Next, the researcher iteratively clusters codes into 12 categories with 31 subcategories and recoded the data within those categories. Next, the authors generate descriptive time series statistics for 30 weeks for both the 12 meta discussion categories (417 instances) and 38 post history type codes (3,284 instances) defined and assigned by Stack Exchange to 1,007 question-answering threads in the Economics main site.

The coding schema evolved from the analysis of meta conversations of the Economics site then is used to guide the content analysis of a purposive sample (322 threads selected based on timeline) of 966 discussion threads from the Mathematics meta site. A combination of closed and
open coding is used. A new category and/or subcategory is added to the coding schema if a particular theme, action or strategy found in the data did not fit any of the existing categories of the schema. At the end of the analysis the coding schema comprised 15 categories with 47 subcategories (Appendix A). The time series statistics for 16 weeks for both the 13 meta discussion categories (717 instances) and post history type codes (21,684 instances) assigned to question-answering threads in the Mathematics main site are also generated for comparison.

3.5. Social Network Analysis

Social network analysis (SNA) is known as an interdisciplinary research design comprised of strategies for identifying and explaining user behaviors in social contexts, named in social networks, in which a user develops relationships by interacting with their peers and other resources (Otte & Rousseau, 2002; Wellman & Berkowitz, 1988). User behaviors and interactions in social networks are captured through a variety of data sources and are presented in graphs with a set of nodes (representing individual users, named actors) and links that connect nodes (representing relationships between actors). The volume and intensity of nodes and links are statistically measured and the density and centrality of the user relationships in social networks are visualized in order to interpret user dynamics and variations in the networks. In social Q&A research, social network analyses were used to capture a variety of user roles and activities or to identify users with certain characteristics, e.g., user expertise or authority. For example, Adamic, Zhang, Bakshy, and Ackerman (2008) investigated knowledge sharing activities, such as the diversity of questions and answers, the breadth of answering, and the quality of answers, using the methods of social network analysis and non-network analysis, i.e., cluster analysis of topic categories. During a month long period, about one million questions, eight million answers, and associated user data were collected using Yahoo! Answers API.
Through social network analysis, creating Q&A networks, the relationships between askers and answerers were examined based on the number of questions and answers users posted or received. Findings indicate that there is a separation of roles in asking and answering questions, and users provide answers in order to help others, or for fun, depending on the topics in social Q&A. The ego network analysis, which investigates the individual activities in the network, indicates that user connectivity differs according to topics; those who provide answers in the topic of “wrestling” are highly connected with others while those who provide answers in the topic of “programming” are not. Also, it was found that those who have high levels of expertise would like to offer answers to all levels of askers, but those who have lower levels of expertise would provide answers to those who have even less expertise.

Bouguessa et al. (2008) assumed that askers in social Q&A would prefer to receive answers from their peer users who are authoritative. The more visibly present authoritative users are in social Q&A sites, the more high-quality and helpful answers could be distributed throughout the sites. They applied several different probability techniques driven from network analysis, such as PageRank, HITS, Z-score, and In-Degree, to calculate the degree of user authority. In a social Q&A site setting, nodes are those who provide answers, and links represent answering behaviors. PageRank is used to decide the ranking of nodes (answerers) in a network, based on the calculation of the number of links attached to a node (the number of answers provided) and their associations with other linked nodes (who provides answers to whom). HITS algorithm is used to identify answerers who act as a hub. The degree of answerers’ authorities can be identified through connections to many good nodes. Z-score calculates the probability of users having authority with the number of questions and answers. In-Degree is measured by the number of nodes that are attached to a node. The answerers with higher InDegree are likely to be more
authoritative. A number of questions and answers given by askers and best answerers were collected from the topic categories of engineering, biology, programing, mathematics, physics, and chemistry in Yahoo! Answers. About 65% of users ask questions only, about 30% of users answer questions only, and about 5% of them ask and answer across the topic categories. 70% of authoritative users across the categories show strong presence in the site, being very active in answering questions.

Social network analysis was used in this study because (a) it is appropriate to visualize data to undercover patterns in user relationships and interactions, and (b) help to identify different types of actors and key users, whom can be recruited as participants for interviews.

3.5.1. Social Network Measures

There are many metrics to analyze social networks. Since the purpose of using social network analysis in this study is to identify the most popular and influential users in each social Q&A site, various centrality measures are used.

Centrality is a measure of the information about the relative importance of nodes and edges in a graph. Centrality measures like Degree Centrality, Closeness Centrality, Betweenness Centrality, Eigenvector Centrality, Katz Centrality and Alpha Centrality play an important role in graph theory and network analysis to measure the importance or prestige of actors or nodes in a network.

- **Degree Centrality**: It is the simplest of all the centrality measures and its value for a given node in the network is the number of links incident on it and is used to identify nodes that have highest number of connections in the network. However it does not takes into account the centrality or prestige of the incident nodes.
• **Closeness Centrality**: The degree of nearness (direct or indirect) between any node and rest of the nodes in the network is represented by “closeness centrality”. It is the inverse of sum of the shortest distance (also called geodesic distance) between a node and rest of all in the network.

• **Eigenvector Centrality**: A more sophisticated version of degree centrality is eigenvector centrality. It not only depends on the number of incident links but also the quality of those links. This means that having connections with high prestige nodes contributes to the centrality value of the node in question. Google’s PageRank and Katz Centrality is a variation of eigenvector centrality and closely related to eigenvector centrality respectively.

• **Betweenness Centrality**: In order to identify the leaders in the network, the quantity of interest in many social network studies is the “betweenness centrality” of an actor. Betweenness centrality measures the fraction of all shortest paths that pass through a given node or in simple terms it quantifies the number of times a node acts as a bridge along the shortest path between two other nodes. Nodes with high betweenness centrality play a crucial role in the information flow and cohesiveness of the network and are considered central and indispensable to the network due to their role in the flow of information in the network. Nodes with the high betweenness act as gate keeper.

• **Clustering coefficient**: It signifies how well a node’s neighbourhood is connected. Clustering coefficient is a measure of the ability of a node’s neighbour to form a complete graph, also called a clique. The value of clustering coefficient is directly proportional to the degree of connectedness of the neighbours of that node: more the connections among the neighbours, the higher the clustering coefficient. The clustering
coefficient of a network is the average of the clustering co-efficient of all the nodes in the network. It is therefore considered to be a good measure if a network demonstrates “small world” behavior.

- **Density**: The Density of a graph quantifies the number of connections between various actors in the network. The graph is considered dense if the number of edges in the graph approaches the maximal number of edges which one can have in that graph and sparse otherwise.

### 3.5.2. Data Pre-processing and Analysis

The format of user interaction on Economics Stack Exchange and Mathematics Stack Exchange is entirely through questions, answers, and comments. A user posts a question, and other users reply directly to that question with their answers. Users can also comment on questions or answers. To preform social network analysis, two asker-replier graphs were created based on question-answer threads and meta discussion threads of two sites. The dataset used included: (1) 166 site managing discussion threads from the Economics meta site, (2) 1,007 question-answer threads from the Economics main site, (3) 966 site managing discussion threads from the Mathematics meta site, (4) 8,559 question-answer threads from the Mathematics main site. The researcher used Python to convert each question/answer, question/comment, and answer/comment pair into a user-to-user (node-to-node) interaction, presented by their user ids. The asker-replier graph of Economics Stack Exchange contained 1526 user interactions and the asker-replier graph of Mathematics Stack Exchange contained 22379 user interactions. Centrality measures were calculated using NodeXL\(^8\) for those two graphs.

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\(^8\) https://www.smrfoundation.org/nodexl/
3.6. Interviews

Qualitative interviewing is a descriptive and interpretive research method that seeks meaning (Brinkman & Kvale, 2009). While interviewers may seek basic facts, explanations, and statistics, nuanced explorations and descriptions of phenomena are of core interest. Interviews in qualitative and mixed-methods research projects are used “to understand themes of the lived daily world from the [participants’] own perspectives” (Brinkman & Kvale, 2009, p. 24), through researcher interpretation of “the meaning of the described phenomena” (p. 27). Interviews for research purposes are often seen as a form of “professional conversation” (p. 2) between the interviewer and the interviewee, on given themes introduced by the interviewer but assumed to be of mutual interest to the interviewee. The two “act in relation to each other and reciprocally influence each other” (Brinkman & Kvale, 2009, p. 32). Interviewees choose specific instances, examples, or areas within the chosen theme(s) to discuss with the interviewer.

Interviews serve as a source of data on phenomena from the past, present, or (potential) future of interviewees, including “persons, events, activities, organizations, feelings, motivations, claims, concerns, … other entities” (Lincoln & Guba, 1985, p. 268), and the complex interrelations between all of these. Interviews can help to verify (member check), extend, and triangulate data and information already obtained via other methods (Lincoln & Guba, 1985). They allow for the gathering of research data when the researcher or his/her colleagues cannot conduct an ethnographic participant observation due to time, location, language, or other constraints (Sutton, 2010).

Qualitative interviews can be categorized into semi-structured interviews and unstructured interviews depending on the degree of structure (Blee & Taylor, 2002). In unstructured interviews, without giving specific questions the researchers let the interviewee to direct the flow
of conversation and introduce and structure the problem in her/his own words corresponding to the broad issues raised by the interviewer. In semi-structured interviews, the researchers create an interview instrument consisting of a list of questions before interviewing, which allows the flexibility to change the order of questions, ask follow-up questions, seek clarifications, and add extra questions during the interview. The researchers are supposed to play a more active role in leading semi-structured interviews than in unstructured interviews. The purposes of semi-structured interviews are to explore, discover, and interpret the meaning of phenomena. Compared to unstructured interviews, semi-structured interviews can ensure the research questions to be addressed. The researchers could retain the flexibility to ask follow-up questions developed from content analysis or participant observations, seek clarifications, obtain explanations and background information, and tailor the interview guide to different interviewees (Murchison, 2010).

3.6.1. Population and Sampling

The unit of analysis chosen for the interview phase of the study is the individual user of Mathematics or Economics Stack Exchange. The broader population of Mathematics or Economics Stack Exchange users totals over 302 thousand people, sampling from this large population would present major logistical challenges. The interview phase will use purposive sampling to recruit key informants from those two sites, participating in question-answering and site managing activities.

The number of key informants to be interviewed depends on the purpose of the study. Brinkman and Kvale (2009) suggested the number of interviews could range from 5 to 25 for a typical interview inquiry. This study interviewed 30 informants from those two sites. The selection of informants is based on the accessibility and active level of potential informants. Stack Exchange
allows their users to list contact information on user profile pages voluntarily, thus the researcher first performed content analysis to identify key informants based on their activity or participation levels at both main and meta sites and then started to contact those potential informants for interviews if his/her contact information is available.

3.6.2. Data Collection

Similar to other qualitative research methods, semi-structured interviews follow a less standardized procedure. Brinkman and Kvale (2009) proposed seven linear steps of conducting semi-structured interviews: (1) preparing by clarifying the purpose of a study, conceptualizing the theme, and obtaining the knowledge of the research topic and local setting; (2) planning the design of the study, including creating an interview guide; (3) conducting interviews following the interview guide, establishing rapport with the interviewee and paying attention to her/his nonverbal expressions with symbolic meanings; (4) transcribing interviews from oral speech to written text; (5) analyzing the interviews based on the purpose and theme of the study; (6) assuring the reliability and validity of the findings; and (7) reporting. There are situations where the researcher may identify new issues during the interview, and thus change the selection of interviewees, revise questions, or modify or drop the original hypotheses. The procedure of interview inquiry can be iterative and circular, going back and forth between different steps. Prior to collection of actual interview data, the interview instrument and procedures was pretested with a pilot study (section 3.6.3). After participants agreed to be interviewed by replying to the email invitation, a specific date and time was arranged for the interview to take place. Interviewees will be offered a choice of Skype, Google Hangouts, Apple FaceTime, or telephone. Interviews were audio recorded, with interviewee permission. The interview process began with introductions, thanking the interviewees for participating, explaining the logistics of
the interview, and ensuring that informed consent is obtained. Participants were directed to an online consent form that requesting their consent for the interviews, including the interview informed consent form, a couple of days before the interview. The interviewer requested interviewees to review this page and ask any questions they had. Before the interview recording begins, consenting participants must sign the consent form. During the interviews the interviewer took any notes she felt necessary on her impressions of the interview as soon as the interview has concluded, to not distract the interviewee with note taking but helped ensure an accurate capturing of the interview process.

3.6.3. Email Interviewing

Email interviewing refers to conducting interviews via email, asynchronously, which allows the interviewees to answer questions at their own pace and over a relatively long period of time. Among a list of varied advantages email interviewing has (McCoyd & Kerson, 2006; Meho, 2006), there are three key benefits that rise to the top based on the nature of this study and characteristics of potential participants: (1) participants are able to answer questions at their own convenience and their own pace thus providing more detailed and rich data; (2) participants from different time zones can be interviewed regardless of the huge time difference, while synchronous interviewing means for one party (interviewer or interviewee) interviewing at night; (3) without the pressures of direct interaction, it is possible to interview potential participants who do not or cannot express themselves as well in talking as they do in writing (identify themselves as shy or insufficiently fluent in English for a video interview, etc.). Email interviewing is well-suited to this study, as it is a good way of producing rich written accounts of user experiences and memories that recollect long-term involvement in the social Q&A communities. Many potential participants are Mathematics or Economics faculty and students.
who live outside of North America and feel difficult to identify a mutually convenient time to talk, email interviewing has more chance to recruit them successfully.

Since social cues of the interviewee are not very important information sources in this study, the major disadvantage of email interviewing becomes the lack of direct probing (Murray & Sixsmith, 1998). Probes or follow-up questions in interviews are generally used to elaborate and clarify participants' responses or to help elicit additional information and depth from informants. Unlike face-to-face and telephone interviews, email interviews do not allow direct probing; it can be done only in follow-up emails, which can take place any time during the data collection and analysis period. The lack of direct probing in email interviews may result in missing some important pieces of data, especially given that not all participants respond to follow-up questions (Meho & Tibbo, 2003). To minimize the weaknesses, several approaches were employed while conducting email interviews: (1) rewrite and pretest interview questions to make sure questions to be asked are clear enough to avoid misinterpretations, break down long questions into small pieces; (2) attach instructions to the participants on completing the interview, including that the more detailed their responses the better, they can use acronyms and symbols that communicate feelings, emotions, and the like, etc.; (3) Check for messages from interviewees regularly and if necessary, summarize the interviewee’s responses to previous questions and return the summary to the interviewee for verification; (4) For those participants who are willing to have a minimum level of interaction, make online calls to explain some of the interview questions that may cause confusion.

3.6.4. Pilot Study

Prior to the main interviews, a pilot study was conducted during December 2016 to February 2017 to (1) pretest the interview protocol and procedures; (2) assess the feasibility and
effectiveness of the recruitment approach. 6 users from Mathematics Stack Exchange and 1 user from Economics Stack Exchange were recruited to participate in the pilot study. 150 recruitment emails have been sent in two rounds to 75 potential participants, 50 from Mathematics Stack Exchange and 25 from Economics Stack Exchange resulting in a 8% participation/response rate. No response was received for the emails sent to the failed Economics Stack Exchange, that one interviewee from Economics Stack Exchange was recruited from the researcher’s personal network. A $30 Amazon gift card was given to each participant. Five interviewees have graduate degrees related to the field the Q&A community focuses on. Three of them are still students, and all of remaining are working in the areas that require subject knowledge that Q&A community they participate in provides.

The initial interview instruments used in the pilot study are developed based on activity theory and the literature review presented in Chapter 2. Pretesting allowed for potential refinement of the interview protocol and procedures, ensuring questions are understandable by interviewees, and making any necessary adjustments to the sampling method for the main interviewing process. Transcriptions and the results of data analysis from this pilot study will be embedded into main interviews.

Some new questions emerged and were added to the instrument, including how they interact with other members outsides of the community, the off-line activities related to the community, their perceptions of high quality questions and answers and how they do quality control especially the informal quality control work flow. The potential need for additional prompting, revisions, and explanations with a few questions were observed. The most important problem was it was difficult for interviewees to follow the concepts in Activity Theory thus answered the related questions effectively.
3.6.5. Interview Protocol Design

The semi-structured interviews rely on an instrument as a guide, but are treated as a conversation guided by the interviewer’s questions and the interviewees’ personal responses and reflections. The instrument provides pre-planned questions and themes, but additional follow-up questions and prompts not included in the instrument emerged from the conversation and its natural progression. This allows key themes related to the research questions to be discussed and focused on without restricting the interview to no more than a given set of questions in advance.

Key themes explored in the interviews include:

- Why did users participate in Math Stack Exchange/Economics Stack Exchange community, how did they get interested in the community;
- Tools, resources, and skills they used to answer questions and participate in other community activities;
- Policies, rules, norms, or division labor that influence their participation;
- Problems and conflicts they encounter in the community and how those problems and conflicts have been resolved;
- Quality control workflow and process they have, both official and unofficial;
- Whether they are familiar with the criteria used by the Stack Exchange system/platform to measure the progress of a Q&A community and do they consider those criteria valid and effective;
- What did they do, or observe the community did to meet those success criteria;
- What are some of criteria and/or measures they consider should be used to assess how successful a Q&A community is.
3.6.6. Data Analysis

All interview audio was transcribed by the researcher, using Audacity software to play back the interview and Microsoft Word to enter the transcription. Data analysis was proceeded in a similar fashion to the content analysis phase of the study. Transcripts and notes were imported into NVivo 11 qualitative analysis software, which was used to look over each file and assign codes. Another fellow doctoral student who is familiar with semi-structured interviews was invited to code part of the data (10% of the question-answering threads and interviews), in order to evaluate the extent of agreement reached on interpreting the data. They discussed and resolved the cases on which they disagreed, and then the author updated her code assignments for other similar cases in the complete dataset. The codes assigned draw from Activity Theory, which serve as a fundamental framework for analyzing the meaning of interview responses. Open codes not included in the list but judged to be emergent in the data and relevant to the study’s purpose and research questions were assigned during the coding process, as recommended by Charmaz (2014) and Brinkman and Kvale (2009).

3.7. Validity and Reliability

3.7.1. Mixed Methods and Case Study

The validity and reliability of mixed methods studies can be assessed in two ways (Creswell & Plano Clark, 2011). One can look at the research as a whole, considering the study’s design, interrelations, and how everything fits together to ensure high levels of validity and reliability. Creswell and Plano Clark provided a list of potential validity threats in mixed methods research and strategies for minimizing these threats (pp. 242-243), which have been followed throughout the design and execution of this research. Similar guidance for case study (Yin, 2013) designs have been followed:
• “Use multiple sources of evidence”: Three different methods of data collection have been used, each sampling across different groups and users from Mathematics Stack Exchange and Economics Stack Exchange.

• “Establish chain of evidence”: The methods are linked together and informed each other. Data from content analysis helps inform the interview protocol, while the social network analysis data help select interview participants. Data from all three methods is tied together in the overall findings and conclusions from the study.

• “Do pattern-matching”: Here Yin refers to looking for “several pieces of information from the same case may be related to some theoretical proposition” (p. 26). This study achieves this by maintaining a consistent focus on the same phenomena throughout all three phases and using the same themes, based on the theoretical framework, or coding the community management discussion threads (in the content analysis phase) and interview transcripts (in the interview phase).

• “Do explanation-building”: Yin refers to establishing a cause-and-effect relationship between patterns in data and theoretical propositions. The pattern-matching above, combines with the Activity Theory, allows such explanations to be developed through synthesis of data from all three phases.

• “Use case study protocol”: Constraints placed on procedures by the two communities are unavoidable, but where possible the same procedures are used for Mathematics Stack Exchange and Economics Stack Exchange. Data dump is collected and analyzed the same way; interview data collected and analyzed the same way.
3.7.2. Qualitative Interviewing

Reliability in qualitative interviewing is defined as “the consistency and trustworthiness of research findings” and it can be evaluated by whether the findings are reproducible by other researchers at other times (Brinkman & Kvale, 2009, p. 245). Reliability measures of qualitative interviewing include the reliability during interviewing (interviewer reliability), transcribing (transcriber reliability), and analyzing (intersubjective reliability).

- **Interviewer reliability** can be influenced by the interviewer’s interviewing technique. To ensure interviewer reliability, before conducting any interview for this study, the researcher had received a sufficient amount of training in qualitative research techniques and practiced interviewing through research projects involving semi-structured interviewing.

- **Transcriber reliability** can be assessed by asking two transcribers to type the same passage of a recorded interview and comparing their transcripts. The researcher plans to self-transcribed all the interviews conducted for this study. To ensure transcriber reliability, another doctoral student with experience in semi-structured interviews and transcription, was invited to transcribe a small number of interviews and review part of the researcher’s transcriptions.

- **Intersubjective reliability** consists of *arithmetic intersubjectivity* and *dialogical intersubjectivity*. *Arithmetic intersubjectivity* refers to the reliability “measured statistically by the degree of concurrence among independent observers or coders” (Brinkman & Kvale, 2009, p. 243). *Dialogical intersubjectivity* refers to the agreement between researchers who are interpreting a phenomenon. Another doctoral student who is familiar with qualitative content analysis and interviews will be invited to code part of the data, in order to evaluate the extent of agreement reached on interpreting the data.
• Brinkman and Kvale (2009) described validity in qualitative interviewing as “the degree that a method investigates what it is intended to investigate” (p. 246). They related this to the reliability of the researcher (e.g., moral integrity, the quality of her previous research), the quality of craftsmanship, and communicative validity. Validation is a continual process that is required in all steps of an interview inquiry.

• The quality of craftsmanship is ascertained by “continually checking, questioning, and theoretically interpreting the findings” (Brinkman & Kvale, 2009, p. 249). Miles and Huberman (1994) suggested several strategies for checking the findings, including examining extreme or critical cases, replicating a finding, weighing the evidence, analyzing rival explanations, following up on unexpected findings, and collecting feedback from key informants.

• Communicative validity refers to “the validity of knowledge claims in a conversation” that involves interviewees, interviewers, researchers, peer scholars, the scientific community, and the general public (Brinkman & Kvale, 2009, p. 253). Communicative validation can be a negotiation between the interviewee and the interviewer, termed member validation, verifying whether the interviewer’s interpretation reflects the interviewee’s understanding of her/his statements (Brinkman & Kvale, 2009).

3.8. Ethical Considerations

This study is not known to have violated any ethical principles or procedures. The content analysis and social network analysis phases used data dump accessible to the public, published by Stack Exchange network/platform, as its source of data. The identities of the users who posted each question-answer threads and community management discussion thread remains confidential. Usernames have been used to allow for identifying authors in a thread, for analysis.
of the flow of conversation, and for identifying potential participants for later phases of the study. Identities have remained confidential throughout the interview phase of the study. Pseudonyms were used in any published or unpublished reports of the results and conclusions, and any other data or information with the potential to identify participants to people familiar with them was altered for the purposes of this dissertation study and future presentation and publication.

Informed consent was obtained from participants in the interview phase, before they participated in the interview. Their participation was voluntary; any participant who wish not to be interviewed was allowed to not take part in or withdraw from the study. If any participant wish to withdraw their data from the study in the future, after already having been interviewed, their interview transcript, interview audio recording, notes taken by the researcher after their interview will be removed from the data collected and analyzed as best as is possible.

The study was explained to participants in all letters they received, in the interview informed consent statement, and in verbal form at the beginning of the interview. As such, participants have had complete awareness of the potential risks and benefits, that their participation is voluntary and the compensation provided, before giving their informed consent for each phase of the data collection. Participants were not deceived in any way at any point during this study. The identity and affiliation of the researcher were known to all prospective participants via the invitation letters and informed consent statements, and the purpose of the interview and reasoning behind it was reiterated to each interview participant at the start of their interview. There were no issues seen with the researcher (as interviewer) maintaining appropriate boundaries with participants during the interview phase of the study.
The FSU Human Subjects Committee, an institutional review board (IRB), has approved this study, including the pilot test of the content analysis and the semi-structured interview phase.

3.9. Data Management

All data from this study are stored in a password-protected secure server. Data dump for content analysis and social network analysis is kept in Microsoft Excel (.xlsx/.csv) format, interview audio in .mp3 format, and interview transcripts in Microsoft Word format. Other relevant documents, such as literature review, consent forms, and emails with informants are also stored in the server as references or guidelines. All research data for this study, including backups, will be deleted and destroyed by April 30th, 2020. Appropriate excerpts from the data and synthesized data analysis, findings, and conclusions—including the completed dissertation, journal articles, and conference papers—may be shared with other researchers, scholars, and the general public up to and beyond the date given above. Future research data and findings building on the data collected and conclusions drawn during this study may be shared with other researchers, scholars, and the general public, subject to restrictions put in place by the researcher’s home institution and funding source(s).

3.10. Conclusion

This chapter presents details of the research design for this dissertation study. The use of content analysis, social network analysis, and semi-structured interviews in sequence within a mixed methods research design addressed the purpose of the research. The next chapter presents findings obtained from this study organized by those three research methods.
CHAPTER 4

FINDINGS

This chapter presents findings obtained from three research methods: content analysis, social network analysis, and qualitative semi-structured interviews. As mentioned in Chapter 3, Content analysis were used to answer all the research questions except those perceptional and psychological questions (e.g. motivations). Social network analysis was used to understand the factors contributing to the success/failure of groups within these networks. Semi-structured interviews were used to address all research questions, especially to collect data that is not available from content analysis.

4.1. Content Analysis

As mentioned in section 3.5, The data used for content analysis is extracted from data dump published by Stack Exchange network. The Economics site spans 30 weeks, from October 2011 when the site entered private beta, to May 2012 when the site was closed. The data used for the Mathematics site spans from July 2010 when the site entered private beta, to March 2015 when the published data ends. Since the Mathematics site graduated from public beta at the end of Week 14, the study used the Mathematics site data from the first 16 weeks for comparison to Economics site. The final dataset used in this study included: (1) 166 site managing discussion threads from the Economics meta site, (2) 3,284 post history records of 1,007 question-answer threads from the Economics main site, (3) 312 user profiles from Economics main and meta sites, (4) 966 site managing discussion threads from the Mathematics meta site, (5) 21,684 post history records of 8,559 question-answer threads from the Mathematics main site, (6) 1131 user profiles from Mathematics main and meta sites.
4.1.1. Demographic Information

The dataset used for content analysis contains 312 user profiles of Economics Stack Exchange and 1131 user profiles of Mathematics Stack Exchange, each including username, reputation, location, age, up/down votes received, self-introduction, and personal website. Based on those user profiles, content analysis identified several user groups on Economics Stack Exchange, including Stack Exchange community managers, Stack Exchange developers, moderators of other Stack Exchange Q&A sites, economics/finance faculty and students, math faculty and students, and business analysts. Groups participating in the activities on Mathematics Stack Exchange include Stack Exchange community managers, Stack Exchange developers, moderators of other Stack Exchange Q&A sites, users of other math-related Q&A sites (e.g. statistics, physics, theoretical computer science, etc.), software engineers, high school math teachers, high school students, private tutors.

<table>
<thead>
<tr>
<th>User Group</th>
<th>Economics Stack Exchange</th>
<th>Mathematics Stack Exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stack Exchange community manager</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Stack Exchange developer</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Moderator of other Stack Exchange Q&amp;A sites</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Economics faculty and student</td>
<td>231</td>
<td>42</td>
</tr>
<tr>
<td>Business analyst</td>
<td>12</td>
<td>NA</td>
</tr>
<tr>
<td>Math faculty and student</td>
<td>56</td>
<td>663</td>
</tr>
<tr>
<td>Software engineer</td>
<td>NA</td>
<td>106</td>
</tr>
<tr>
<td>User of other math-related Q&amp;A sites</td>
<td>NA</td>
<td>178</td>
</tr>
<tr>
<td>High school math teacher</td>
<td>NA</td>
<td>52</td>
</tr>
<tr>
<td>High school student</td>
<td>NA</td>
<td>32</td>
</tr>
<tr>
<td>Private tutor</td>
<td>NA</td>
<td>34</td>
</tr>
</tbody>
</table>
4.1.2. Activities

The content analysis identified six types of activities on Economics Stack Exchange: (1) creating and editing posts (questions, answers, or comments to questions or answers); (2) creating and editing tags; (3) assigning tags to questions; (4) voting up or voting down posts; (5) voting to close or reopen questions; (6) migrating questions; (7) assigning posts to be community-owned. Mathematics Stack Exchange has two more activities as (8) developing and maintaining tools to facilitate content development and (9) flagging posts. The four activities of Economics meta sites are: (1) participating in site management discussion; (2) inviting other users to participate in discussion; (3) assigning tags to meta discussion post; (4) voting up or voting down posts.

Mathematics meta sites has two more activities as (5) moving meta discussion to chat rooms; (6) linking site management discussion post to main site threads. Discussion topics of two meta sites are not considered as activities and presented in section 4.1.5.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Economics SE</th>
<th>Mathematics SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main site—creating and editing posts</td>
<td>620</td>
<td>3867</td>
</tr>
<tr>
<td>Main site—creating and editing tags</td>
<td>134</td>
<td>534</td>
</tr>
<tr>
<td>Main site—assigning tags to questions</td>
<td>595</td>
<td>2865</td>
</tr>
<tr>
<td>Main site—voting up/down posts</td>
<td>1568</td>
<td>14625</td>
</tr>
<tr>
<td>Main site—voting to close or reopen questions</td>
<td>220</td>
<td>285</td>
</tr>
<tr>
<td>Main site—migrating questions</td>
<td>113</td>
<td>326</td>
</tr>
<tr>
<td>Main site—assigning posts to be community-owned</td>
<td>34</td>
<td>464</td>
</tr>
<tr>
<td>Main site—developing and maintaining tools</td>
<td>NA</td>
<td>37</td>
</tr>
<tr>
<td>Main site—flagging posts</td>
<td>NA</td>
<td>67</td>
</tr>
<tr>
<td>Meta site—participating in site management discussion</td>
<td>174</td>
<td>295</td>
</tr>
<tr>
<td>Meta site—inviting other users to participate in discussion</td>
<td>18</td>
<td>87</td>
</tr>
<tr>
<td>Meta site—assigning tags to meta discussion posts</td>
<td>59</td>
<td>426</td>
</tr>
<tr>
<td>Meta site—voting up/down posts</td>
<td>378</td>
<td>897</td>
</tr>
<tr>
<td>Meta site—moving meta discussion to chatting rooms</td>
<td>NA</td>
<td>42</td>
</tr>
<tr>
<td>Meta site—linking to main site threads</td>
<td>NA</td>
<td>68</td>
</tr>
</tbody>
</table>
4.1.3. Division of Labor

In Activity Theory, Division of Labor refers to “both the horizontal division of tasks between members of the community and the vertical division of power and status”. Stack Exchange network defines the vertical division of power and status thus there is no difference between those two study sites with respect to this. The content analysis identified three types of accounts: the Stack Exchange employees, the moderators of individual social Q&A site, and other registered users. The Stack Exchange employees are community managers or developers from Stack Exchange network to observe how a Q&A site evolves. They have specific privileges such as making decision and update the criteria for graduating or closing a Q&A site. Moderators are elected through popular vote by users of each Q&A site. Site moderators have the privileges to lock posts, protect questions, merge questions and tags, approve tag synonym, see more data such as voting statistics and user profile information, place users in time suspension or delete users. Registered users are ordinary users of a Q&A site. Although their accounts do not have differences, the reputation points a registered user earns controls what he/she can do on the Q&A site. Each Q&A site could customize how many reputation points is required for a specific privilege.

There is no systematic distribution of tasks among users. Cluster analysis has been conducted based on user ids associated with codes of activities on main site and categories of discussions on meta site. To identify horizontal division of labor, k-mean cluster analysis was conducted based on the associations between User ID and main/meta site activities. The number of clusters was determined using elbow method with human judgement. There are in total 5 clusters and 9 clusters (horizontal division of labor) were identified for Economics SE and Mathematics SE.

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https://math.stackexchange.com/help/privileges
4.1.3.1. **Horizontal Division of Labor of Economics Stack Exchange**

Participants of Economics Stack Exchange can be divided into *administrators, content creators, site management commenters, registered users* and *visitors*, in terms of the horizontal division of their tasks. *Administrators* are those who perform site management tasks including creating chat rooms, casting post as off-topic, duplicated, or community-owned, and communicating with Stack Exchange if the community itself is unable to solve certain issues. *Content creators* are those who create or make comments on others’ posts on the main site. *Site management commenters* are those participate in meta site discussions. *Registered Users* vote up or down answers on main site or site management proposals on meta site. *Visitors* are those visit the main site and check content on a regular basis.

4.1.3.2. **Horizontal Division of Labor of Mathematics Stack Exchange**

While the tasks of administrators, site management commenters, voters, and users are the same as those of Economics Stack Exchange, the horizontal division of labor of Mathematics Stack Exchange is more complex and distributed, including additional roles as *content curators, metadata curators, tool developers, and gatekeepers*. *Content curators* can be divided into content creators and content editors who edit others’ questions or answers. *Metadata curators* can be divided into metadata creators who create tags and tag synonyms and edit tag wiki, and metadata annotators who assign tags to posts. *Tool developers* are those who respond to feature requests, develop and maintain tools, and report bugs and other technical issues. *Gatekeepers* are those who perform tasks of user education or quality control including editing community wiki, flagging posts, reporting spams, and removing new user restrictions.
Table 4.3. Horizontal Division of Labor of Economics SE and Mathematics SE

<table>
<thead>
<tr>
<th>Horizontal Division of Labor</th>
<th>Economics Stack Exchange</th>
<th>Mathematics Stack Exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrator</td>
<td>3 (1%)</td>
<td>8 (0.7%)</td>
</tr>
<tr>
<td>Content creator</td>
<td>13 (4.2%)</td>
<td>66 (5.8%)</td>
</tr>
<tr>
<td>Content editor</td>
<td>NA</td>
<td>18 (1.6%)</td>
</tr>
<tr>
<td>Commentator</td>
<td>12 (3.8%)</td>
<td>42 (3.7%)</td>
</tr>
<tr>
<td>Metadata curator</td>
<td>NA</td>
<td>32 (2.8%)</td>
</tr>
<tr>
<td>Tool developer</td>
<td>NA</td>
<td>12 (1.1%)</td>
</tr>
<tr>
<td>Gatekeeper</td>
<td>NA</td>
<td>18 (1.6%)</td>
</tr>
<tr>
<td>User</td>
<td>68 (21.8%)</td>
<td>852 (75.3%)</td>
</tr>
<tr>
<td>Visitor</td>
<td>216 (69.2%)</td>
<td>83 (7.3%)</td>
</tr>
</tbody>
</table>

4.1.4. Meta Site Discussion

Content analysis of meta site discussion identified 14 categories with 49 subcategories of site management discussion topics. Some categories are unique to Economics or Mathematics meta.

Table 4.4. Comparison of Meta Discussion of Economics SE and Mathematics SE

<table>
<thead>
<tr>
<th>Economics Stack Exchange (Number/Percentage)</th>
<th>Mathematics Stack Exchange (Number/Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Scope Development (114/29.4%)</td>
<td>Site Scope Development (114/15.9%)</td>
</tr>
<tr>
<td>Define scope (43), Clarify/Enforce scope (30), Site goal discussion (NA), Specific question handing (36), Closed question discussion/dispute (NA), Scope overlap (with other site) discussion (5)</td>
<td>Define scope (24), Clarify/Enforce scope (9), Site goal discussion (14), Specific question handing (41), Closed question discussion/dispute (24), Scope overlap (with other site) discussion (2)</td>
</tr>
<tr>
<td>Community Governance (77/19.8%)</td>
<td>Community Governance (139/19.4%)</td>
</tr>
<tr>
<td>Site policy discussion (17), Site policy clarification (NA), Explanations/Ask for explanations (NA), Moderation discussion/expectations (8), Conflict mediation/consensus-seeking (NA), Vandal/spam fighting (NA), Site Status reporting/evaluation (11), Site promotion (2), Call for participation/contribution/vote (14), Other governance issues (25)</td>
<td>Site policy discussion (30), Site policy clarification (15), Explanations/Ask for explanations (18), Moderation discussion/expectations (19), Conflict mediation/consensus-seeking (14), Vandal/spam fighting (6), Site Status reporting/evaluation (5), Site promotion (9), Call for participation/contribution/vote (14), Other governance issues (9)</td>
</tr>
<tr>
<td>Community Development Strategies (21/5.4%)</td>
<td>Community Development Strategies (14/2.0%)</td>
</tr>
<tr>
<td>Membership and Role Management (20/5.2%)</td>
<td>Membership and Role Management (87/12.1%)</td>
</tr>
<tr>
<td></td>
<td>Economics Stack Exchange (Number/Percentage)</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td></td>
<td><strong>Table 4.4-continued.</strong></td>
</tr>
<tr>
<td>Target user group analysis (NA), User recruiting (4), Expert recruiting (4), User behavior regulations (5), User education (3), Moderator election/feedback/complaint (5)</td>
<td>Target user group analysis (8), User recruiting (2), Expert recruiting (1), User behavior regulations (14), User education (43), Moderator election/feedback/complaint (19)</td>
</tr>
<tr>
<td><strong>Reward System (NA)</strong></td>
<td><strong>Reward System (26/3.6%)</strong></td>
</tr>
<tr>
<td></td>
<td>Reward System (26/3.6%)</td>
</tr>
<tr>
<td></td>
<td>Content Development (32/8.2%)</td>
</tr>
<tr>
<td></td>
<td>Content format requirement (4), Reference/source requirement (5), Management tool development (21), Editing tool development (NA), Duplicated content management (2)</td>
</tr>
<tr>
<td></td>
<td>Question asking strategies (12), Question editing/rephrasing (8)</td>
</tr>
<tr>
<td><strong>How Answer Question (12/3.1%)</strong></td>
<td><strong>How Answer Question (11/1.5%)</strong></td>
</tr>
<tr>
<td></td>
<td>Question answering strategies (10), Answering editing (2)</td>
</tr>
<tr>
<td><strong>Quality Control (19/4.9%)</strong></td>
<td><strong>Quality Control (16/2.2%)</strong></td>
</tr>
<tr>
<td></td>
<td>Question concern/evaluation (8), Quality control action (11)</td>
</tr>
<tr>
<td><strong>Feature request/suggestion (11/2.8%)</strong></td>
<td><strong>Feature request/suggestion (22/3.1%)</strong></td>
</tr>
<tr>
<td></td>
<td>Metadata/controlled vocabulary development (17), Classification (2), Archiving (2)</td>
</tr>
<tr>
<td><strong>Benchmarking with Other Communities (41/10.6%)</strong></td>
<td><strong>Benchmarking with Other Communities (43/6.0%)</strong></td>
</tr>
<tr>
<td></td>
<td>Experiences from other sites (16), Site comparisons (12), Propose other similar sites (13)</td>
</tr>
<tr>
<td><strong>Site Design (NA)</strong></td>
<td><strong>Site Design (69/9.6%)</strong></td>
</tr>
<tr>
<td></td>
<td>Site Design (69/9.6%)</td>
</tr>
<tr>
<td></td>
<td>Front page/dashboard design (18), General interface design (17), Domain name suggestion (23), Site name suggestion (4), System/script error reporting (7)</td>
</tr>
<tr>
<td><strong>Site Closing Process (29)</strong></td>
<td><strong>Site Closing Process (NA)</strong></td>
</tr>
<tr>
<td></td>
<td>Site Closing Process (NA)</td>
</tr>
<tr>
<td></td>
<td>Migrate questions (11), Future plan (13), Other reflection (5)</td>
</tr>
</tbody>
</table>

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4.1.5. How Community Success Criteria Shape Community Dynamics

Content analysis of policy pages of Stack Exchange identified criteria and evaluation metrics used by Stack Exchange to evaluate community status and decide if a Q&A community should move to next phase. The first two sets of evaluation metrics are hard limits—a Q&A site will move to next phase once it meet the requirements of evaluation metrics.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Evaluation Metrics</th>
<th>Community Development Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition–Commitment:</strong> Have enough potential users Have a clear defined site scope</td>
<td>Number of followers (at least 60 followers) Number of example questions reaching certain quality levels (at least 40 questions with a score of 10 or more)</td>
<td></td>
</tr>
<tr>
<td><strong>Commitment-Private beta:</strong> Have enough committers agreeing to participate in the beta phase</td>
<td>Number of committers (at least 200 committers) Number of committers reaches certain reputation levels (100 committers with at least 200 rep on a single site) Commitment Score based on committers’ activity on all other sites and how old the commitment is (at least 500 points)</td>
<td>Recruit high-reputation users from other Stack Exchange Q&amp;A sites (Economics &amp; Mathematics SE)</td>
</tr>
<tr>
<td><strong>Private beta-Public beta:</strong> Have useful content and community building activities at the appropriate level</td>
<td>No hard limit and published metrics</td>
<td>Set different site scopes in private beta and public beta phases (Economics SE) Avoid unknowable or highly opinionated questions (Economics SE)</td>
</tr>
<tr>
<td><strong>Public beta-Launched site:</strong> Have reasonably good quality contents; Have a sufficiently large core community and sustainable community growth</td>
<td>Hard limit (does not guarantee launched once met): Duration (at least 90 days), Number of high reputation users (at least 10 users with 2,000+ reputation and at least 5 users with 3,000+ reputation)</td>
<td>Post “pseudo” questions (Economics SE) Answer out-of-scope questions (Economics SE)</td>
</tr>
</tbody>
</table>
Although the activities occurred in both main and meta sites may not directly reflect the possible change of community dynamics, content analysis of site management discussion found members of both Q&A sites used some strategies to meet those criteria set by Stack Exchange to help the site move to the next phase. The Economics site has 21 (13%) discussion threads of such community development strategies while the Mathematics site has 14 (1%) such discussion threads. The community development strategies used in Economics site include: (1) set different site scopes in private beta and public beta phases; (2) avoid unknowable or highly opinionated questions; (3) post “pseudo” questions (questions that do not seek for answers) which users normally not consult others for; (4) answer all unanswered questions even if those questions did not fall into the intended scope; (5) recruit high-reputation users from other Stack Exchange Q&A sites. The Mathematics site instead mainly focused on recruiting high-reputation users. Although users of Mathematics site also cared about daily traffics, they devoted more efforts on improving the quality of the questions and answers by editing the content instead of just posting comments or new answers.

4.2. Social Network Analysis

4.2.1. Network Description and Measures

By connecting members who ask questions to members who answer/comment on them, asker-replier graphs (who answer/comment on who) are generated for both Mathematics and Economics sites. Figure 4.1 shows a part of the direct graph of Economics Stack Exchange, in which the starting nodes represent answerers, the end nodes represent askers, and an edge represents a question-answering activity.
Since social network analysis is mainly used in this study to identify most popular and influential members in each site, various centrality measures (both local and global) are used. Centrality is measured by the degree of the various nodes in the network, with degree representing number of other nodes to which a node is adjacent. This measure of centrality is known as local centrality since indirect connections to the particular node are ignored. Thus the notion of centrality has been extended to global centrality to include the distant connections of nodes. This is measured by the closeness of the nodes to other nodes expressed in terms of the distances among the various nodes. Betweenness is another centrality measures which measures the extent to which a particular node lies between other nodes of the network. A node of relatively low degree may play an important intermediary node (e.g. broker, gatekeeper, etc) and hence be a central node in the network. Eigenvector is another measure of centrality proposed based on the belief that the centrality of a particular node cannot be assessed in isolation from the centrality of all the other nodes to which it is connected. Centrality scores in Eigenvector measure are assigned to nodes based on the principle that connections to high-score nodes contribute more to the score of the particular node than connections to low-score nodes. Results of group metrics are included in
Table 4.6. Here nodes represent users and Edges represent interactions between users. Except the in-degree and out-degree, all other metrics were calculated based on undirected graphs.

Although the Mathematics network is larger than the Economics, the cohesion and density of these two networks are similarly low. The values of average clustering coefficient also indicate that the egocentric networks are not dense. At community level, the values of Closeness and Eigenvector centrality of two networks are also very similar, while the average in/out degree and Betweenness of mathematics network is larger than those of the Economic network.

<table>
<thead>
<tr>
<th>Group Metrics</th>
<th>Economics SE</th>
<th>Mathematics SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodes</td>
<td>293</td>
<td>1063</td>
</tr>
<tr>
<td>Edges</td>
<td>977</td>
<td>7221</td>
</tr>
<tr>
<td>Self-Loops</td>
<td>128</td>
<td>637</td>
</tr>
<tr>
<td>Strongly Connected Component (SCC)</td>
<td>99.7%</td>
<td>99.6%</td>
</tr>
<tr>
<td>Max Vertices in a Connected Component</td>
<td>292</td>
<td>1059</td>
</tr>
<tr>
<td>Max Edges in a Connected Component</td>
<td>976</td>
<td>7217</td>
</tr>
<tr>
<td>Max Geodesic Distance (Diameter)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Average Geodesic Distance</td>
<td>2.82</td>
<td>2.66</td>
</tr>
<tr>
<td>Graph Density</td>
<td>0.0099</td>
<td>0.011</td>
</tr>
<tr>
<td>Modularity</td>
<td>0.40</td>
<td>0.43</td>
</tr>
<tr>
<td>Average In-Degree/Out-Degree</td>
<td>3.334</td>
<td>6.793</td>
</tr>
<tr>
<td>Average Betweenness Centrality</td>
<td>531.62</td>
<td>1749.42</td>
</tr>
<tr>
<td>Average Closeness Centrality</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Average Eigenvector Centrality</td>
<td>0.003</td>
<td>0.001</td>
</tr>
<tr>
<td>Average Clustering Coefficient</td>
<td>0.128</td>
<td>0.203</td>
</tr>
</tbody>
</table>

4.2.2. Degree Distribution

Figures 4.1 shows the Cumulative Distribution Function of in-degree and out-degree of two sites. Both in-degree and out-degree are applicable only for directed graph. In network theory in-degree represents the number of edges incoming to a node, while out-degree represents the number of edges outgoing from a node. In this study, in-degree was calculated by the number of unique members a node/user has received replies from, and out-degree was calculated by the
number of unique members a node/user has replied. These figures show that the users differ in their activity level in both sites. Some answered many questions; others merely stopped by to ask or answer a question or two. On the other extreme, there were users who asked or answered dozens of questions. Although both sites display heavy tailed distributions, Mathematics site has broader in-degree distributions, with a few people receiving many answers and comments. In contrast, the most active users posing questions on Economics site initiated threads garnering only a few dozen answers.

![Graphs showing cumulative distribution function of in-degree and out-degree for Economics and Mathematics SE](image)

**Figure 4.2. Cumulative Distribution Function of In-degree and Out-degree of Economics SE and Mathematics SE**

### 4.2.3. Betweenness Centrality

60 users (20.3%) on Economics site and 142 users (11.5%) on Mathematics site are considered as brokers because their betweenness scores are above the average. While the user network of the Economics site is much smaller than that of the Mathematics site, the percentage of broker it has is higher. Figure 4.3 presents the results of betweenness score and subnetwork affiliation of each node/user that calculated automatically by NodeXL. Here betweenness score is calculated by the number of shortest paths from all other nodes to all others that pass through that node. Without
nodes that have a high betweenness, the whole network will become disconnected. The figure shows that high betweenness nodes of the Mathematics site are more concentrated and dispersed over fewer subnetworks (marked in different colors). On the other hand, high betweenness nodes of the Economics site are more dispersive and scatter over more subnetworks.

Figure 4.3. Betweenness Centrality of Economics SE (Left) and Mathematics SE (Right)

There are two possibilities of those brokers: they can be leaders who hold authority over and control collaboration in the network, or users who happen to be on the periphery of different clusters. To examine what kind of brokers they are, the researcher mapped user ids of those brokers to the division of labor identified in cluster analysis (section 4.1.3.1 and section 4.1.3.2). The results showed that most brokers on the Economics site—43 out of 66 nodes (65%)—were identified as ordinary users who maintained a minimum level of activities, while most brokers on the Mathematics site—105 out of 142 nodes (74%)—were high-profile users such as administrators, content creators and editors, tool developers, and gatekeepers. This indicates that most high betweenness nodes on Mathematics site represented leaders or core members, but most users with high betweenness nodes on Economics site were users happened to be on the periphery of different user groups. In other words, the network of Mathematics Stack Exchange
was connected by a group of core community members who were dedicated to preform various community activities. Thus the whole network was more stable and other members who were connected through those core members may also have more interactions. On the other hand, network of Economics Stack Exchange was connected largely by ordinary users thus the network was not that stable—it was much easier for an ordinary user to leave the community compared to a core member, and then a part of the network would be disconnected. The situation could be even worse considering the results in section 4.2.4, the neighbors of a user were also not connected to each other. If an ordinary user with high betweenness score left the community, his/her neighbors would not be connected to the main network.

Table 4.7. Integration Results of User Role based on Horizontal Division of Labor and Betweenness Centrality

| Administrator (2/3.3%), Content creator (7/11.7%), Commentator (8/13.3%), User (31/51.7%), Visitor (12/20%) | Administrator (8/5.6%), Content creator (25/17.6%), Content creator (27/19.0%), Content editor (13/9.2%), Commentator (12/8.5%), Metadata curator (17/12.0%), Tool developer (8/5.6%), Gatekeeper (15/10.6%), User (13/9.2%), Visitor (4/2.8) |

4.2.4. Analysis of Ego Networks

Ego network consists of a certain user, other people the user interacts with directly, and interactions between them. All users from both sites are examined to identify local patterns of interactions. Figure 4.4 and Figure 4.5 below show 50 random selected ego-networks of each site. Users of the Mathematics site are more likely to be “discussion persons” because their neighbors are themselves highly connected. On the contrary, users of the Economics site are more like “answer people” because most of their neighbors, the people they are helping, are not
connected. If a certain user leaves the network, the entire ego-network will be disconnected, which could result in high membership turnover and is not a good sign of a healthy network.

Figure 4.4. Ego Networks of Mathematics SE

Figure 4.5. Ego Networks of Economics SE
4.3. Semi-structured Interviews

4.3.1. Demographics of Interviewees

Of the 30 interviewees, ten were from the failed Economics SE and twenty were from the Mathematics SE. Among those ten interviewees from Economics SE, two served as moderators and eight were ordinary members, all of them participated in the Q&A site from very beginning, when the site was at Definition or Commitment phase. 80% of the interviewees had a doctoral degree in economics when they started to participate in the site, and 20% had a master degree. All degrees were in economics. In terms of gender, 90% were male and 10% were female. In terms of profession, six of the interviewees were either associate and assistant professors in economics or business school, two were doctoral students in economics, and two worked as consultants for private sections.

Among those twenty interviewees from Mathematics SE, five were moderators and fifteen were ordinary members. Nine of them joined the Q&A site when it was at Definition or Commitment phase, while another six started to participate from public beta phase. 65% of the interviewees had a doctoral degree, 15% had a master degree, 10% had a bachelor’s degree, and 10% had high-school degree. Their degrees were in pure or applied mathematics, computer science, or astrophysics. In terms of gender, 80% were male and 20% were female. In terms of position, five of the interviewees were retired professors, associate and assistant professors, or clinical professors/lecturers in mathematics, three were postdoc research fellows in mathematics, three were software development engineers, one was research fellow in Microsoft, two were high school math teachers, and two were high school students. Some of them also held other professional positions, such as mathematical society officials and math competition collaborators. Three of them worked as private tutors as a part-time job. All demographic
information was based on the time when they participated in Mathematics Stack Exchange or Economics Stack Exchange rather than the time they were interviewed.

4.3.2. Activities

The object of the Mathematics Stack Exchange and the Economics Stack Exchange was the same: to build a successful subject specific Q&A community on Stack Exchange network. Table 4.11 shows activities in Economics SE and Mathematics SE identified from the interview data. These activities can be categorized in eight board groups: (a) content development, (b) content organization, (c) quality assurance, (d) user management, (e) tool development, (f) communication, (g) promotion, (h) moderation. Each of these categories has subcategories. *User management* and *tool/feature development* and some subcategories in other six categories were only found in Mathematics SE.

<table>
<thead>
<tr>
<th>Account Status</th>
<th>Economics Stack Exchange (10)</th>
<th>Mathematics Stack Exchange (20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 moderators, 8 users</td>
<td>5 moderators, 15 users</td>
</tr>
<tr>
<td>Education Level</td>
<td>8 have doctoral degree, 2 have master degree</td>
<td>13 have doctoral degree, 3 have master degree, 2 have bachelor’s degree, 2 have high-school degree</td>
</tr>
<tr>
<td>Profession</td>
<td>6 faculty in Economics/Business, 2 doctoral students, 2 consultants of private section</td>
<td>5 faculty in mathematics, 3 postdoc fellows in mathematics, 3 IT-related engineers, 1 research fellow from industry, 2 high school math teachers, 2 high students</td>
</tr>
<tr>
<td>Gender</td>
<td>9 males, 1 female</td>
<td>16 males, 4 females</td>
</tr>
<tr>
<td>Location</td>
<td>7 in North America, 3 in Europe</td>
<td>8 in North America, 8 in Europe, 4 in Asia</td>
</tr>
<tr>
<td>Age</td>
<td>Age 27 to 42</td>
<td>Age 18 to 69</td>
</tr>
<tr>
<td>Category</td>
<td>Activity on Economics SE</td>
<td>Activity on Mathematics SE</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Content Development (4.3.3.1)</td>
<td>Posting question or answers</td>
<td>Posting question or answers</td>
</tr>
<tr>
<td></td>
<td>Reading questions or answers</td>
<td>Reading questions or answers</td>
</tr>
<tr>
<td></td>
<td>Making comments to questions or answers</td>
<td>Making comments to questions or answers</td>
</tr>
<tr>
<td></td>
<td>Editing questions or answers</td>
<td>Editing questions or answers</td>
</tr>
<tr>
<td></td>
<td>Reviewing suggested edits*</td>
<td>Posting bounties to invite answers*</td>
</tr>
<tr>
<td>Content Organization (4.3.3.2)</td>
<td>Creating tags</td>
<td>Creating tags</td>
</tr>
<tr>
<td></td>
<td>Deleting tags</td>
<td>Deleting tags</td>
</tr>
<tr>
<td></td>
<td>Reviewing tags</td>
<td>Reviewing tags</td>
</tr>
<tr>
<td></td>
<td>Assigning and Removing tags</td>
<td>Assigning and removing tags</td>
</tr>
<tr>
<td>Quality Assurance (4.3.3.3)</td>
<td>Upvoting or downvoting questions, answers, comments</td>
<td>Upvoting or downvoting questions, answers, comments</td>
</tr>
<tr>
<td></td>
<td>Closing off-topic, opinion-based, or low quality posts</td>
<td>Closing off-topic, opinion-based, or low quality posts</td>
</tr>
<tr>
<td></td>
<td>Reopening closed questions</td>
<td>Reopening closed questions</td>
</tr>
<tr>
<td>User Management* (4.3.3.4)</td>
<td>Educating new users*</td>
<td>Regulating user behaviors*</td>
</tr>
<tr>
<td></td>
<td>Regulating user behaviors*</td>
<td>Mediating conflicts among users*</td>
</tr>
<tr>
<td></td>
<td>Accessing user database*</td>
<td>Accessing user database*</td>
</tr>
<tr>
<td></td>
<td>Banning IP address*</td>
<td>Banning IP address*</td>
</tr>
<tr>
<td></td>
<td>Suspending user account*</td>
<td>Suspending user account*</td>
</tr>
<tr>
<td>Tool/Feature Development* (4.3.3.5)</td>
<td>Developing moderation tools*</td>
<td>Writing and updating user tutorials*</td>
</tr>
<tr>
<td></td>
<td>Requesting features on meta*</td>
<td>Requesting features on meta*</td>
</tr>
<tr>
<td></td>
<td>Responding to feature requests*</td>
<td>Responding to feature requests*</td>
</tr>
<tr>
<td></td>
<td>Reporting bugs on meta site*</td>
<td>Reporting bugs on meta site*</td>
</tr>
<tr>
<td>Communication (4.3.3.6)</td>
<td>Discussing site policies and issues on meta</td>
<td>Discussing site policies and issues on meta</td>
</tr>
<tr>
<td></td>
<td>Reading meta posts</td>
<td>Reading meta posts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Talking to other users in SE chat rooms*</td>
</tr>
</tbody>
</table>
### Table 4.9-continued.

<table>
<thead>
<tr>
<th>Category</th>
<th>Activity on Economics SE</th>
<th>Activity on Mathematics SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Promotion</strong></td>
<td>Inviting new users</td>
<td>Inviting new users</td>
</tr>
<tr>
<td><em>(4.3.3.7)</em></td>
<td></td>
<td>Maintaining site blog*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Promoting site using other platforms*</td>
</tr>
<tr>
<td><strong>Moderation</strong></td>
<td>Reviewing posts in the review queues</td>
<td>Reviewing posts in the review queues</td>
</tr>
<tr>
<td><em>(4.3.3.8)</em></td>
<td>Performing status analysis</td>
<td>Performing status analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Locking posts*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Communicating with SE management team*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Editing script code*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Determining site stage*</td>
</tr>
</tbody>
</table>

#### 4.3.2.1. Content Development

Activities of content development centered around creating question-answer threads regarding specific subject (mathematics or economics) or site management from interview data, confirming what have been reported in content analysis. Besides questions and answers, comment was another important component in content development and used for various purposes, such as asking for clarifications, providing short answers, explaining administration decision, or giving a hint. The last two activities—*Reviewing suggested edits* and *posting bounties to invite answers*—were not found in content analysis and only reported by interviewees from the Mathematics Stack Exchange. An associate professor in math explained why he thought posting comments should be encouraged for decision clarification:

> I think there is a group of people who use the [Mathematics] SE was very quickly closing questions; I think it’s harmful to the site. If a new user asked a question, there is a group that really quickly closed it, and I found it’s a little harsh. I personally will prefer person will leave a comment, let the user kind of fix the question for a while rather than, well, immediately shut it down. (M—P14)
Another clinical professor in math, whose position focused on teaching and administration, explained why he preferred to give hints in comments, although it was discouraged on Mathematics SE:

Sometimes I make a comment, might be a strong hint towards the answer. That is technically discouraged. They don’t want you to put comments, they want you to put an answer. But I think it’s just simpler to give a hint in comments. Other times I might make a comment, as an educator, saying you need to fill in more to this question before you get a good answer. (M—P10)

Interviewees from Mathematics SE also did lots of editing work, including editing questions or answers posted by editors themselves or by others. Interviewees stated they edited questions more frequently than answers because they considered answers presented more originality, although by policies both questions and answers on Mathematics SE are community-owned. Most editing work intended to fix format or grammar issues in content, as one PhD student in computer science explained:

I will sometimes edit people’ questions, especially if it’s formatted badly or if they don’t use MathJax format. I edited answers less commonly. There is a small cohort of users who are good at editing questions that make the English better. They seem to be fanatic about fixing spelling errors to replacing the original question title with a better one. (M—P5)

Interviewees from Mathematics SE also reported they have improved or rejected other users’ suggested edits. One interviewee described the process of reviewing others’ suggested edits:

Those users without enough reputation to edit would have their edits placed in the Suggested Edits queue. If two other high reputation users approved an edit, then it is published. If one rejected and one approved, then it needed another user to review. As a reviewer, you can
improve or reject and edit a suggested edit. The improve option will approve the edit, while the reject and edit option will reject it. But I usually don’t reject others’ edits because many rejected suggested edits will block a user from suggesting more for a while. If I don’t agree with others’ edits I just leave it there. (M—P9)

A bounty is a special reputation award given to answers. It is funded by the personal reputation of users and users can attach a bounty to questions to help attract more attention and more answers. There is no need to be the asker of the question to offer a bounty on it. Interviewees from Mathematics SE mentioned they had experiences of posting bounty to invite more answers, but the effect was not as good as expected:

Users can offer reward or certain reputation points if others answer this question, if they really want someone to look at this question, then give some of your reputation points as reward, and somebody will do that. However, a very hard question may require a day of work or thinking, and the reward of answering that question is similar to answering lot of easy questions. For those answerers who just try to get much points as possible, the more efficient way to get points is to answer a brunch of easy questions. So a lot of times even if with the bounty, it seems it’s not worth the effort. (M—P7)

4.3.2.2. Content Organization

Activities of content organization can be loosely categorized into two groups: (a) activities around tags, and (b) activities around duplicated questions. The second group was only reported by interviewees from Mathematics SE. Most content organization activities except *deleting tags* (an activity that can only been performed by moderators) have also been identified in content analysis.
Activities around tags included creating, editing, reviewing, deleting, assigning, and removing tags. One postdoc in math, who was also a moderator of Mathematics SE, describing the process of tag creation, editing, and deletion as follows:

Any user has a certain amount of reputation can add a tag. They cannot remove, only moderators can remove tags. For example, a year or two years ago, we ended up completely destroy the homework tag, people cannot use it anymore. They [users] can edit tags, although if a user, say 5000 reputation would add a tag—what really happens is tags are added poorly and needed to be reviewed by a certain number of users to be functional, and all moderators are notified by the editing of new tags. We spend some times to get rid of the new tags, because new tags are often bad. For actually creating a tag? I haven’t actually created a tag for a really long time. I think most tag actions happened maybe in the first eighteen months. (M—P11)

Another interviewee from Economics SE explained the process of assigning and removing tags:

What happens is when you start to type a tag, the system starts to suggest a bunch of tag options. There is no automatic tag suggestion or assignment. Based on those two or three letters, the system will start to give suggestions. There are also several times when I was editing others’ questions, I will remove or change some tags to make more sense. When you are changing tags, what you really do is to fix incorrect tags by substituting them with the correct tags. Users need to have a certain number of reputation point to do this. Whenever you see questions being repeatedly tagged with the incorrect tag, or multiple tags that mean the same thing, you can propose a change, they call it as creating tag synonym. Any suggested synonyms for the tag will appear below that with up and down arrows so that eligible users can vote on whether it is valid or invalid. When a tag synonym reaches a vote score of a
certain number, it is accepted and becomes active. If a tag synonym reaches a vote score of, I think a negative number, it will be deleted. (Economics Stack Exchange—P4)

Interviewees from Mathematics SE mentioned they devoted to close questions if a question has been asked before and already has an answer. One moderator from Mathematics described the process of closing duplicated questions as follows:

A duplicated question can be flagged to close or vote to close. The original question must have an answer; we cannot mark a question as a duplicate of an unanswered one. A moderator or a user has earned a gold tag badge in one of that question's current tags can close a duplicated question directly, while it takes 5 close votes from other users to close a duplicated question. A vote to close as duplicate will automatically post a comment with the duplicate link if no one else had voted for that particular duplicate. The user who cast the vote is the owner of the comment and can edit or delete it like any other comment. Once the question is closed as a duplicate, these comments are deleted and the duplicate information is automatically edited into the question itself. Some duplicate questions may eventually be deleted, but often they are left as a signpost pointing people towards the canonical answer to that question. If someone does not agree with that it truly is a duplicate, he or she can try to get it reopened by casting a reopen vote. But most reopen cases were unsuccessful. (M—P2)

Moderators can choose to migrate a duplicated question into another question. One moderator explained the question migration process as follows:

First one of the questions must be closed as a duplicate of the other. We are pretty conservative in question migration, unless the answers on the question-to-be-merged make perfect sense on the target question. If that’s the case, the answer from the post will be moved to the other and the question will be auto-locked, with the notice changed from "marked as
duplicate" to "merged". It is also possible to migrate a question to another SE site, such as Math Overflow. But that needs approval from their moderators. We can also accept question migration from other sites. I probably did one or twice but moderators of Math Overflow rejected the migration requests. (M—P8)

4.3.2.3. Quality Assurance

The interview data has identified five quality assurance activities, while three of them—Upvoting or downvoting questions, answers, comments, Closing off-topic, opinion-based, or low quality posts, Reopening closed questions were shared between both communities and previously identified in the content analysis. Voting up and down is how the community indicates which questions, answers, or comments are most useful and appropriate. All interviewees reported that they voted up and down very often and it was the most commonly used mechanism to control content quality—when voting up, they were moving that content up so it could be seen by more people.

Interviewees also mentioned they frequently closed questions or answers that are considered as off-topic, opinion-based, or low quality. There were two way of closing posts, either by flagging the posts for community attention or by casting close and reopen votes. One moderator of Economics described the closing and reopen process as follows:

You will need a certain amount of reputation to flag posts to close an off-topic, too board, opinion-based question or an answer that you consider is not an answer, or any post that presents very low quality. There are guidelines on meta site defining the characteristics of each category, but the judgement could be very subjective and the guidelines are always in development. Then the flag will enter a specific review queue and be handled by other community members who have earned review privileges. I think some flags can be handled
by the system itself, perhaps comment flag? Moderators may step in to handle flags that aren't handled by ordinary members or the system. Flags that aren't processed in a reasonable amount of time will expire. If you are a high reputation user, you can also cast close vote for a question. It only works for questions if I remember correctly. It takes 5 votes to reach the closing threshold and close votes also expire if the threshold is not reach after several days.

Any post which has an active close vote or a close flag will appear in the Close/Reopen Votes review queue. In that queue, users can either vote to close the question, edit the question, or recommend leaving it open. Edits or a sufficient number of Leave Open reviews will remove the question from review. If the question receives another close vote after being kicked out, it will re-enter the queue for further review. Similarly, the reopen queue contains any post that currently has an active reopen vote. Users can vote to reopen, edit the question, or leave the question closed. A certain number of Leave Closed votes will again kick the question out of the queue and begin the reopen vote aging process, and of course, another reopen vote will put it back into the queue. My experience was once a question entered the close review queue, in most cases it would not get enough reopen votes. (E—P5)

Moderators of Mathematics SE mentioned the community devoted more efforts to handle spams and abusive posts. Although the closing and dispute process of those two types of posts were similar to that of others, both moderators and other ordinary members treat those posts more seriously since they clearly violate community policies:

    Spam or rude or abusive flags received an extremely high priority in the moderation queue and came with severe penalties. For example, if a question has 3 red flags is banished from the front page and all question lists. Post will be locked and deleted, and the author loses 100 reputation if receiving 6 red flags. Other problematic posts will not result in penalties to the
authors. Spam and rude or abusive flags can be retracted like all other flags, and they also expire after four days if the thresholds aren't reached. These flags can also be cleared by moderators, but this will cause the flags to be marked as disputed, even though they may have been marked helpful in the past. So we are very careful when dealing with them. (M—P11)

Stack Exchange community team had the authority to track votes to see who voted on who to ensure there was no unusual traffic, according to several moderators from Mathematics SE.

### 4.3.2.4. User Management

The interviews with members of Mathematics SE allowed identifying a set of activities regarding user management, which were missing in activities drawn from content analysis but were mentioned in some meta discussion posts on both Economics meta and Mathematics meta. The most frequently mentioned activities were *educating new users* and *regulating user behavior*. A tenured lecturer in applied math explained why and how he participated in these two activities:

New users face a learning curve independent from their level of mathematical sophistication. The site has developed its norms, do’s and do-not’s that are somewhat different from what they seem to have expected. I usually gave some comments and sometimes edited their questions. For example, I posted links of user tutorials in comments. I’m happy to help students who are, maybe 30% or 50% done with the question but are missing some pieces. I’m happy if I can support those missing steps. On the other end, a lot of students, or users, just copy and paste the questions, or take a picture of the question, I tried to discourage those kinds of behaviors by down voting or flagging those questions. (M—P16)

If conflicts between users escalated to editing wars or close/open wars (the question is closed and then reopened and then closed again, etc.), moderators would step in and forcefully stopped all
actions on a given question or answer. One moderator of Mathematics SE described the mediation process:

Stack Exchange gives moderators a set of software tools to e.g. forcefully stop all actions on a given question. Nobody enjoys such kindergarten-nannying, but sometimes we are glad to have that option. When I was campaigning for moderator position I entertained hopes of resolving a few such conflicts with humor, but I have since learned that it doesn’t work to defuse a situation where there are several people present already high on adrenaline. Once flags for editing or close/open conflicts are getting raised, moderators will step in, and stop it. Our first cause of action usually is just to make everything calm down, because we don’t want flags and flags more, that’s annoying. There is a secret, private moderator chat room where moderators sit down and chat with each other, reach some sort of consensuses, and then they do, then that is what happened. (M—P17)

However, there was no general process to handle fights between moderators, except removing them from the moderator role. One moderator mentioned an early case when two moderators having conflicts:

You have bigger problems when two moderators get in a fight about how to handle something. By design moderators can overrule anything, including each other. I think several years ago, two moderators ended up suspending each other, and they unsuspended themselves because they can do that. They both deleted and undeleted questions, and one of them actually deleted another moderator. By the time we called the [Stack Exchange] community team, they just came in, they suspended both. They had to spend a week to try to reinstall everything. Usually you just be very careful about deleting important users, but that moderator really did.
Now we have backups, probably that’s not very hard, but that’s the first time it happened. (M—P11)

Other user management activities such as suspending users’ accounts, banning IP addresses, or access user database to check user information depended on the privilege system. As one moderator (M—P5) stated: “one of the most common, really annoying problems is sometimes you have a user posts badly, and they are suspended [by moderators], and they just make another account, and get suspended, and make another account and get suspended. And you can actually check information in user database and ban an IP address as posted by an account, but moderators cannot do that only [Stack Exchange] super community team can.”

4.3.2.5. Tool/Feature Development

Similar to user management, a set of activities of tool and feature development were identified from interviews with members of Mathematics SE, which were missing in activities drawn from content analysis but appeared in some meta discussion posts. Several moderators and high-reputation members of Mathematics SE devoted lots of efforts to write web apps and scripts for editing, data-gathering, and moderation tasks\(^\text{10}\). Some of those tools were published for public use or even adopted by Stack Exchange management team. One moderator gave an example:

The smoke detector, an automatic low-quality post detector, was written and updated by a couple of members of the community. It is an official cession SE asked now since they like it, they used the API a lot, they used to have a special token from SE, but it’s actually written and developed by just some random people. I have a thing displays Latex which doesn’t run on the site, which allows me to display Latex that was not allowed on the site. I wrote it in JavaScript. (M—P11)

\(^{10}\) https://normalhuman.github.io/
Another activity they kept on doing is writing and updating user tutorials, with an emphasis on Mathjax\textsuperscript{11} and how to ask and answer effectively\textsuperscript{12}. Users can request features or report bugs on meta site with certain tags, and Stack Exchange management team would respond if those features should be provided or whether the bug has been fixed. One interviewee described process of feature requesting as follows:

They [Stack Exchange management team] are active on meta, there are some meta tags for questions, which are ‘discussion’, ‘support’, ‘bug’, ‘feature’—I guess there are four—if a question is tagged with one of these, the community team will see. If it is with a bug tag, the community team needs to see if they need to change the code. Also for feature request to look at, they need to mark it as status-accepted or status declined, based on if they will make this feature to happen or not. The SE staff are open to new ideas and suggestions from us. At least as long as we keep in mind that some features that would work well in the math site would not be well received elsewhere, and some compromises are necessary. (M—P13)

4.3.2.6. Communication

All communication activities-- Discussing site policies and issues on meta, Reading meta posts, and Talking to other users in SE chat rooms--have been previously identified in content analysis. Interviewees from both Economics SE and Mathematics SE communicated their thoughts of site policies and issues on meta sites. All moderators mentioned they spent a lot of times posting on meta since they were very aware of the status and policies of the site. Other interviewees read a lot of meta posts to learn the site policies, although not all of them were very actively posting.

\textsuperscript{11} https://math.meta.stackexchange.com/questions/5020/mathjax-basic-tutorial-and-quick-reference
\textsuperscript{12} https://math.meta.stackexchange.com/questions/9959/how-to-ask-a-good-question
Interviewees from Mathematics SE used chat rooms very often. As mentioned in section 4.3.3.4, moderators had a private chat room where all moderators sit down and chatted with each other to reach some sort of consensuses for moderating issues. Other users could also set up a chat room for any topic related to Mathematics SE\(^\text{13}\), and such chat rooms were often used for discussions related to a subfield in math, site policies, and conflict resolving. As one interviewee stated: “I don’t use the chat very often, but I know lots of people do. There is community talking to each other, sometimes it happens to the comments but lot of times it happens to the chat.” (M—P12)

4.3.2.7. Promotion

Interviewees from both sites mentioned the user invitation activity, which was also found in content analysis. Another two site promotion activities—Maintaining site blog and Promoting site using other platforms—were only reported by interviewees from Mathematics SE and haven’t been identified in content analysis. One moderator mentioned he was responsible for editing a blog associated with Mathematics SE:

Another thing is MSE has an associated blog, supported by SE model. One of the other moderators was very excited about having that blog. But then some personal things happened in his life and he stepped down as a moderator and left the site. Then I took over the blog. This was the creation of the blog, asking for initial topics, saying what should or should not happen on the site, things like this. (M—P1)

Some other interviewees from Mathematics SE had experiences of promoting the site with other platforms, such as Facebook, Twitter, Reddit, and internal discussion boards and mailing lists. They have sought help from American Mathematical Society to distribute information about Mathematics Stack Exchange. As one interviewee (M-P5) mentioned, they also promoted the site

\(^\text{13}\) https://chat.stackexchange.com
in their daily life: “Sometimes, someone has asked me a question, and I don’t know the answer to that, I will suggest that you could probably post an answer on MSE. I let people use the site in this way, by helping them getting answers of their questions.” Site promotion via internal platforms and personal network in daily life were reported to be more effective than social networking sites.

4.3.2.8. Moderation

The interview data identified a set of moderation activities, which was all missing in content analysis, although some of the moderation ideas have been discussed in table 4.4. Except the first two activities in table 4.11, other moderation activities were only reported by interviewees from Mathematics Stack Exchange. The most frequently mentioned activity was to review flagged posts in review queues. Review queues, also known as review tasks, contain posts that possibly need community attention, as determined by the system or other community users. A post with a flag will enter a specific review queue based on the flag type. Most interviewees who have enough reputation to preform review tasks mentioned they clicked through different review queues to review edits and flags quite often. One interviewee from Mathematics SE (M-P16) explained the review process as follows:

Over half time I spent on responding user’s flags, killing spams, or resolving one user’s attack on another that was flagged for moderator intervention, we don’t allow this kind of thing on the site. What constitutes a review depends on the queue. All review queues have one consistent option called skip. This option permanently skips the post and you won't see it in the same review queue again. I usually only check the Late Answers and First Posts queue and Low Quality Posts queue. The Late Answers and First Posts queue contains answers which were posted much later than the question and the first few posts asked by
new users. You can edit the post, vote on it, add a comment, upvote a previously existing comment, or set the post as no action needed. The \textit{Low Quality Posts} queue contains posts which were automatically determined to be of low quality by the system or flagged as low quality by users. You can set a post as look OK if you feel it does not need improvement, or if the post cannot be salvaged, you can recommend to close the question or delete the answer. All these options depend on if you have earned certain privilege. Then if the post is a question, it will enter the close votes queue. If it’s an answer and receives a certain number of deletion recommendation, it will be deleted. Yes there are some other types of review queues such as Close/Reopen Vote queue and Suggested Edits queue, but I don’t deal with them very often.

Moderators of Mathematics SE mentioned they sometimes locked posts for the following reasons: (a) multiple users were edit-warring or rollback-warring a post over and can't decide which revision to keep, (b) a post that attracted many off-topic or irrelevant comments that should be taken to the site's chat instead, (c) a question that got opened and closed repeatedly many times without achieving community consensus on whether it should stay open or closed, (d) a post where repeated voting or editing was happening in a way which attempted to game the system, (e) a question that continued to attract flame posts, spam, or other inappropriate answers. Moderators of both Economics and Mathematics SE performed site status analysis and regularly reported the statistics on meta site. Only moderators can lock posts, other users can flag it for moderator attention and explain why they think a post should be locked. A locked post can be unlocked by moderators but it seldom happened.
Moderators and ordinary users of Mathematics SE used meta site to keep touch with the SE community team for issues occurred in moderation. One moderator stated the Stack Exchange management team would check meta posts with certain tags regularly:

For most problems that come up, the problem will be attached to the moderators, and usually we have handle them. For a while a big problem comes up and we call this super community team of super power to handle it. They are active on meta, there are some meta tags for questions, which are ‘discussion’, ‘support’, ‘bug’, ‘feature’—I guess there are four—if a question is tagged with one of these, the community team will see. They read the ‘discussion’ and ‘support’ posts sometimes. They are a little bit more active on somebody else’s SE sites, especially on those ones are in beta. Like I have been a moderator forever. So the community team knows me, what I do and don’t do, so they don’t look over me so much. But the community team is far more involved in other smaller SE sites. (M-P1)

The highest-level moderation activities, such as determining site stage, designing graphic elements of a site, or editing script code were only available to SE community team.

4.3.3. Subject

According to Engeström (1990), subject in Activity Theory refers to a people work as part of a community to achieve the object. The interview data analysis identified three groups of subject existing: (a) researchers, (b) educators, and (c) students. The latter two groups were only reported by interviewees of Mathematics SE. The researchers were those community members who cared more about the research values of a Q&A site. They focused on finding and solving interesting subject specific problems and communicated research ideas with peers. All interviewees of Economics SE identified themselves as researchers, which was consistent with the community goal they set—to build a Q&A site for at least graduate-level questions in
educators were those community members who emphasized the teaching aspect of a Q&A site, putting most of their efforts to help others to learn or to practice their teaching skills. Among those twenty interviewees of Mathematics SE, eight identified themselves as educators. Some of them used Mathematics SE as a resource of developing teaching materials or a platform to demonstrate teaching ability and engagement. Students were those who used the site as a study tool to improve understanding of certain concepts. The focus of a certain member may change based on the change of his/her own status. Although no interviewee of Mathematics SE currently identified themselves as students, four of them reported that they used to be in the student group before they changed to educators or researchers.

4.3.4. Motivation

All interviewees from Economics SE discovered the site through either Area 51 or other SE Q&A sites, such as Cross Validated SE or Latex SE. The reasons why they decided to participate in Economics SE included: have fun to ask and answer questions, improve understanding of course contents, learn new concepts in economics, share professional knowledge. All of them have some experiences in other SE Q&A sites, such as Math Education, History of Science, and Academia, but didn’t mention any other platform they used outside of SE to discussion economic questions. The preference of the SE model (reputation accumulation policy, distributed moderation, and the embedded Latex system) is also an important reason why they participated in Economics SE site.

Interviewees of Mathematics SE joined Mathematics SE by referral of colleagues and friends, professional organizations such as American Mathematical Society, or through web searching and other SE sites including Math Overflow and Latex SE. The participation motivations reported by Mathematics SE interviewees were more diverse, and both intrinsic and extrinsic.
Intrinsic motivations included: (a) have fun to ask and answer questions, (b) relieve stress, (c) help others to learn, (d) find interesting math questions, (e) challenge him/herself with math research problems. Extrinsic motivations included: (a) improve understanding of course contents, (b) learn new math concepts, (c) practice written or teaching skills, (d) find example questions used in work, (e) demonstrate engagement in teaching. Compared to the participation motivations of Economics SE, interviewees of Mathematics SE mentioned more extrinsic reasons, such as social recognition or feedback when preforming activities. One interviewee, who was a postdoc research fellow in model theory (Mathematics Stack Exchange—P7) said: “I do the badges on my academic website, linking to my SE profile. I’m now the top 2% answerers on MSE. When I apply for jobs next Fall, I will mention it in my teaching statement. It’s an evidence about my engagement with the community, helping people learning.” Another interviewee, who was a clinical professor in math (M—P4), mentioned he use questions on Mathematics SE in assignments and exams: “As a teacher, I always look up for good questions. What happens a lot on the math SE is that, new users are working on homework questions for their math classes. So a lot of times I found interesting problems professors have assigned to those students. When I’m looking for sources for my homework or exam questions on the same topics I will refer to those questions”. All interviewees of Mathematics SE had experiences of using other online platforms to discussion math questions, including: (a) other social Q&A site such as Yahoo Answer! And Quora, (b) math mailing lists, (c) usenet group such as sci.math, sci.math.research, rec.puzzles, (d) online math forums such as XKCD Math, My Math Forum, The Art of Problem Solving, (e)discussion website such as reddit, (f) social network site such as Facebook, (g) other SE sites such as Math Overflow and Math Educator. The format of social Q&A site and the feature design of SE network are two important reasons why they switched to
and continuously participated in Mathematics SE. As one interviewee (M—P6) stated: “I like the concept of a Q&A site where answers are “peer-reviewed” so that the best answers tend to float up to the top.” The integration of mathjax was mentioned by several interviewees: “Other platforms usually don’t have nice text formatting integrated, the user interfaces are usually not so advanced. So from the beginning I was very happy that Math Overflow and Mathematics SE exist, because SE network seems like a real effective way, a good platform to ask and answer questions.” (M—P12)

Table 4.10. Intrinsic and Extrinsic Motivations of Participating in Economics/Mathematics SE

<table>
<thead>
<tr>
<th></th>
<th>Economics Stack Exchange</th>
<th>Mathematics Stack Exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intrinsic Motivation</strong></td>
<td>Have fun to ask/answer questions, Share professional knowledge</td>
<td>Have fun to ask/answer questions, relieve stress, help others to learn, find interesting math questions, challenge him/herself with math research problems</td>
</tr>
<tr>
<td><strong>Extrinsic Motivation</strong></td>
<td>Improve understanding of course contents, Learn new concepts in economics</td>
<td>Improve understanding of course contents, Learn new math concepts, Practice written or teaching skills, Find example questions used in work, Demonstrate engagement in teaching</td>
</tr>
</tbody>
</table>

4.3.5. Rules

According to Activity Theory, rules refer to explicit or implicit norms, conventions, regulations that enable or limit activities (Engeström, 1990). The interview data analysis identified a set of explicit and implicit rules regulating the activities on Economics SE and Mathematics SE.

Explicit Rules refer to those policies set by Stack Exchange system and were applied to each Q&A site in the same way. Implicit rules were those policies that haven’t been stated in explicit terms but were agreed and executed by community members. Implicit rules may vary by site. For
example, all SE sites can set their own policies of defining and handling out of scope questions.

4.3.5.1. **Explicit Rules**

**Be nice**: this policy is set to regulate users’ behaviors such as name-calling, harassment, bullying, inappropriate language or attention, or bigotry of any kind. Stack Exchange network encourages users to actively report behaviors that behavior that is rude, offensive, unproductive or speak up if they have been harassed. If a post receives flags consistently, it will be removed and the account of the content owner could be suspended for a few days or several months. Users are also asked to contact the Stack Exchange management team directly if they feel staff attention is necessary—although contacting the management team directly is not encouraged for any other issue. This policy also requires users not to reply abusive, off-topic, or inappropriate content because doing so would provide undue attention thus encourage such behaviors.

**Privilege system based on reputation points**: the setting of privilege system regulates most activities of content development and moderation. Privileges control what users can do on Stack Exchange. For example, users with enough reputation points can vote to close, delete posts immediately, or view deleted posts. Such design was used to encourage and reward different types of valued activities, encourage participations, reduce moderation workload of official moderators, and help new users to understand community norms before they carried out more advanced level tasks.

**Discuss and search on meta site**: the function of meta site on Stack Exchange is similar to the talk pages on Wikipedia. Users are encouraged to discuss the workings and policies of a certain Stack Exchange site with other users, moderators, and Stack Exchange management team on meta site. Discussion topics include, but are not limited to: how the site works, policies and community decisions, bug reporting, improvement suggestion, new feature proposal, etc. Each
meta post must have at least one tag, including support, bug, feature-request, and discussion. Users are asked to first search to see if their questions have been asked before and do some research about how the meta site works before they post.

**Flagging and flag review:** users are asked to create flags to bring inappropriate content to the attention of the community rather than handling it by themselves. The most common flag types include spam, rude or abusive, not an answer, duplicate question, off-topic, too board, opinion-based, and low quality, in need of moderator intervention. Users should pick up a flag type and specify why they feel the flag is necessary. A sufficient number of spam and abusive flags will result in automatic deletion, while other flags need to go to different review queues for those users who have review privileges to handle. To reduce the review workload, users who have higher level privileges (e.g. close question privilege) are asked to act directly. For example, if a user has the privilege to immediately close a question instead of flag it to close. Such practice is common between other higher level and lower level privileges (e.g. vote to close question/close question directly).

**4.3.5.2. Implicit Rules on Economics SE**

**Homework questions:** Economics Stack Exchange site aimed at building a platform for graduate-level economics questions which emphasizing the research aspect, thus homework questions were not allowed on the site. According to interviewees of Economics SE, a mix of low-level and graduate level questions was not welcomed by the community, although filtering questions using embedded tag system was technically applicable. Thus the implicit rule of handling a homework question was just voting it down, flagging it to close, or closing it directly, depending on what kind of privilege the user has.
Out-of-scope questions: since Economics Stack Exchange site kept a narrowed scope, policies regarding out-of-scope questions was also relatively strict. Compared to homework questions, out-of-scope question were relatively difficult to argue. Thus when users took actions to close an out-of-scope question, they were required to leave a comment to explain why the question was voted/flagged to close or closed directly.

4.3.5.3. Implicit Rules on Mathematics SE

Homework questions: Mathematics Stack Exchange allowed but did not encourage home-work question. One moderator mentioned there used to be a homework tag, and they eventually destroyed that tag because they felt it had users explicitly say they were asking their homework questions on the site. The agreement reached by the researcher community and the educator/student community was the community would not appreciate questions that are of the form “answer this homework question” and expected the asker to explain his/her thoughts on the problem while asking it. Otherwise the question would be voted/flagged to close or closed directly and comments should be left to explain why this question should be closed. As one interviewee (M-P10) who identified himself as educator explained the general practice of how to deal with homework questions: “When I first started, it used to be—people will say you cannot post homework questions on the website. Later the consensus people seem to reach is you can post homework questions but you need provide sufficient context, you have to provide your work, you have to say what’s your thoughts on the problem, or maybe say what’s your level like you are in high school or college or graduate school. It can be a little frustrating if one question is posted only with the question statement without any other input from the users.”

Out-of-scope question: Mathematics Stack Exchange encouraged users to first check site scope before they posted questions and had slightly boarder scope in practice than what has been listed
on meta site. Identifying out-of-scope questions was a community-driven process, users can cast close votes or flag the question if they felt the question is out of scope. As one moderator (M-P1) stated: “If you don’t know anything about the site and go to the how to ask question section on meta, you will see a very clear set-up topic scope, even been called what questions can I ask here. Inside what can be asked is slightly boarder than, which you will get better impression by actually reading the rules. MSE is different from any other SE site in that, we allow some opinion based questions, which is very rare; we allow big list questions, because sometimes people ask things like what are some questions that can be proven by really big theories. Almost no other SE site allowed this. If you just read the rules, you will think you are not allowed to ask them, but we actually do.”

**Edit war**: moderators typically don’t step in unless two users edit the same thing within relatively short period of time, For example within a week or less, more than four times. Once it happened, then moderators stepped in and stopped it. Then what moderators actually do, they will decide on a case-by-case basis.

**Tag review**: mathematics Stack Exchange allowed any user has a certain amount of reputation to add tags. Users cannot remove, only moderators can remove tags. They can edit tags and all moderators are notified by the editing of new tags. Newly-added tags needed to be reviewed by a certain number of users to be functional. Moderators of Mathematics SE mentioned that they spent times to get rid of some new tags, because new tags were often bad.

### 4.3.6. Division of Labor

#### 4.3.6.1. Vertical Division of Labor

The interview data analysis identified four official roles based on the vertical division of power and status, including *Stack Exchange community team, moderators, registered users*, and
visitors. There was no difference between Economics SE and Mathematics SE regarding the vertical division of labor, since official roles were set by Stack Exchange network.

The Stack Exchange community team consisted of SE managers and developers, who were actual SE employees. They have specific privileges such as determining site stage, designing in-site tools and features, testing scripts, accessing user data, deciding site policies, or even replacing moderators. Moderators acted as a liaison between the community and Stack Exchange network. Moderators have specific privileges such as locking posts, protecting questions, placing users in timed suspension, deleting users, performing large-scale maintenance actions (merging questions and tags, tag synonym approvals, etc.), and contacting the Stack Exchange team directly.

Moderators can also see more data in the system, including vote statistics (but not ‘who voted for this post’) and user profile information. Registered users were those who have accounts on Stack Exchange but hadn’t been elected as moderators. Every Stack Exchange Q&A site has specific privilege system that controlled what users can do based on their reputations. High reputation users can perform most tasks a moderator can do, such as viewing deleted posts, deleting closed question, or editing tag wikis without needing approval. Visitors are those who didn’t have accounts on the site. Beside reading posts, visitors, who are credited as ‘community user’, can interact with others in a certain number of ways---they can propose edits that go to special queue, which need to be approved by an additional user. They could also flag posts, click the up vote or down vote button, although it’s actually nothing.

4.3.6.2. Horizontal Division of Labor

Table 4.9 shows the horizontal division of labor/informal roles based on their tasks. Similar to the findings of content analysis, two roles were only found from Mathematics SE: Quality Manager and Grassroots Level Managers.
The primary Administrators are those community members whose have moderator titles and
staffs from Stack Exchange network. Some ordinary community members who have high
reputation also served as administrators. In terms of tasks, administrators are responsible for
activities of user management, tool development, and moderation. Except staffs from Stack
Exchange network, all other administrators used to take other roles such as content creators,
reviewers, or quality managers. Content creators are those community members who mainly
focused on activities of content development and content organization.

Figure 4.6. Horizontal Division of Labor of Economics Stack Exchange
• Closing off-topic, opinion-based, low quality posts
• Reopen closed questions
• Deleting tags
• Locking posts
• Tracking votes
• Accessing user database
• Banning IP address
• Suspending user account
• Inviting new users

• Educating new users, regulating user behaviors
• Mediating conflicts among users
• Talking to other users in SE Chat rooms
• Discussing site policies
• Developing moderation tools
• Responding to feature requests
• Maintaining site blog
• Performing status analysis
• Editing script code
• Determining site stage

• Closing duplicate questions
• Upvoting or downvoting posts
• Locking posts
• Closing off-topic, opinion-based, low quality posts
• Reopen closed questions
• Flagging spams or abusive posts
• Requesting features on meta
• Performing status analysis
• Communicating with SE management teams

• Editing questions or answers
• Reviewing suggested edits
• Reviewing tags
• Reviewing posts in review queues

• Editing questions or answers
• Making comments to questions or answers
• Assigning and removing tags
• Migrating questions
• Reporting bugs on meta site

• Posting questions, answers, comments
• Making comments to questions or answers
• Posting bounties to invite users

• Reading questions, answers, comments
• Upvoting or downvoting questions, answers, comments
• Reading meta posts

Figure 4.7. Horizontal Division of Labor of Mathematics Stack Exchange
**Quality managers** are those who mainly performed quality assurance tasks and some moderation tasks including performing status analysis, locking posts, and communicating with SE management team. Interviewees of Mathematics SE mentioned quality managers were very passionate about closing questions. **Grassroots Level Managers** are those who focused on copy-editing work and cleaning up old contents, making the whole repository more useful and searchable. **Reviewers** are those who devoted most of their time and effort to deal with flags in various review queues. **Users** are those community members who mainly consumed content and sometimes upvoted or downvoted posts.

The researcher also mapped the user ids of those thirty interviewees to the results of content analysis (section 4.1.3) and social network analysis (section 4.2.3). Among the twenty interviewees of Mathematics Stack Exchange, six were administrators, five were gatekeepers, three were tool developers, four were content creators, two were commentators based on the results of content analysis. All of them had both high In-degree and Out-degree, and their betweenness scores were above average based on the results of social network analysis. Regarding those ten interviewees of Economics Stack Exchange, three were administrators, four were content creators, three were users based on the results of content analysis. Five of them had both high In-degree and Out-degree, four have high out-degree but low in-degree, one had low out-degree but high out-degree. Seven of them had higher betweenness scores above average while three had lower betweenness scores.

**4.3.7. Tools**

The interview data analysis generates a typology of tools that help user to participate in Economics SE and Mathematics SE. These tools can be divided into ten categories: (a) question answering resources, (b) content editing tools, (c) searching and browsing tools, (d) computation
tools, (e) graphic design tools, (f) programming tools, (g) communication tools, (h) moderation tools, (i) user education tools. Some categories were only reported by interviewees of Mathematics SE and include both internal and external tools. *Internal tools* refer to those tools offered by the Stack Exchange system. Therefore, there was no difference regrading internal tools between Economics SE and Mathematics SE. *External tools* refer to those tools existing outside of the Stack Exchange system or developed by users themselves.

**Table 4.11. Internal and External Tools Identified By Interview (* Means This Tool Was Only Reported By Interviewees of Mathematics SE)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Internal tool</th>
<th>External tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question Answering</td>
<td>Questions and Answers on SE network</td>
<td>text books and notes, Wikipedia, web searches*, online math knowledge repositories*</td>
</tr>
<tr>
<td>Content Editing</td>
<td>Stack Exchange editor, embedded Latex renderer</td>
<td>LyX*, self-developed editing tools*</td>
</tr>
<tr>
<td>Searching and Browsing</td>
<td>embedded tag system</td>
<td>self-developed filters*</td>
</tr>
<tr>
<td>Computation*</td>
<td></td>
<td>Mathematica*, WolframAlpha*, Maple*</td>
</tr>
<tr>
<td>Graphic Design*</td>
<td></td>
<td>Pinta image editor*, GeoGebra*, Inkscape*, desmos*</td>
</tr>
<tr>
<td>Programming*</td>
<td></td>
<td>Python*, R*</td>
</tr>
<tr>
<td>Communication</td>
<td>comments, meta site, chat room</td>
<td>emails*</td>
</tr>
<tr>
<td>Moderation</td>
<td>Stack Exchange privilege system</td>
<td>self-developed moderation tools*</td>
</tr>
<tr>
<td>User Education</td>
<td>Help center, meta site</td>
<td>self-developed user tutorials*</td>
</tr>
</tbody>
</table>

**Question-answering resources:** the question-answering resources that the interviewees used to help them formulate questions and answers included, but were not limited to, questions and answers on SE network, textbooks and notes, Wikipedia, web searches, other online math repositories such as Wolfram Alpha, The On-Line Encyclopedia of Integer Sequences, Interactive Mathematics Miscellany and Puzzles, and Arxiv. These tools were mainly used
remind them of definitions or look up terms they didn’t know, and to provide useful links in the answer.

**Content editing tools:** the most frequently used content editing tools are those that allow users to write mathematics in Latex. Most interviewees mentioned they were pleased with the embedded Latex renderer and they don’t need to other editing tools outside of the Stack Exchange system. For longer answers, some of them used Lyx external Latex editors. Interviewees of Mathematics SE mentioned they developed other content editing applications to copy comments, correct misspellings, format link to a webpage or a tweet, convert Lyx-produced latex markup to markdown/mathjax suitable for SE.

**Searching and browsing tools:** the major searching and browsing tool that the interviewees used was the embedded SE tag system. Most interviewees mentioned they used the tag system to identify and avoid questions in certain topics. As one interviewee (M-P7) stated: “I focus on the tags which are interested to me. I focused on the model theory tag, most of my answers are in that tag. But I also look at related things I’m interested in—logic tag, general topology and category theory. I think you may get complaints about thousands of easy calculus questions and too many users going to the site just to get their homework questions done form other interviewees? I cannot speak of that...That’s not a big problem for me because I use tags as question filter.” Unlike Math Overflow, Mathematics SE allows non-research oriented questions, therefore the embedded tag system is extremely important to differentiate questions based on users’ objectives. Interviewees of Mathematics SE have also used some self-developed searching tools to identify unanswered questions tailored to their own preferences.

**Computation, Graphic design, and Programming tools:** those three categories were only mentioned by interviewees of Mathematics SE. Computation tools such as Mathematica,
WolframAlpha, and Maple were used to perform or verify results of computation; Graphic design tools such as Pinta image editor, GeoGebra, Inkscape, desmos were used to create diagrams; programming tools such as Python or R were used to write small programs or demos.

**Communication tools:** communication tools are those that facilitate the communication within users. The interview data analysis identified four types of communication tools: comments, meta site, chat rooms, and emails. The comment function was designed to encourage talking about questions and answers without posting new answers. Interviewees of both sites mentioned they used comments to ask for clarification, suggest corrections, or reply to certain users. Meta site was mainly used to ask questions about how the site work, or about policies and community decisions, especially between ordinary users and moderators/SE management team. Chat rooms offered real-time discussion spaces focusing on certain topics, while moderators have their own private chat rooms to discuss moderating issues.

**Moderation tools:** the most frequently mentioned moderation tool is the internal privilege system. The privilege system controls what moderation work users can do based on their reputations. Interviewees of Mathematics SE mentioned they developed several moderation tools to track unanswered questions, pending reviews, possible low-quality posts, recently active questions with titles that are likely to need improvement, posts with unusual traffics, etc.

**User education tools:** user education tools are those that help new users get familiar with the site policies or community norms. The interview data analysis identified three types of user education tools: the Help Center section, the meta site, and the self-developed user tutorials. The Help Center section collected frequently asked questions (FAQ) addressing issues regarding how to ask and answer question and how the reputation, badges, and privilege systems are designed. All interviewees agreed that new users should first go through the Help Center section before
they actually post content. The meta site served as an archive of community policy discussions, community decision, and community status analysis. For example, one moderator of Mathematics SE (M-P11) mentioned he always posted explanations of community decision and status reports on meta site. Interviewees of Mathematics SE also mentioned some moderators and high reputation users devoted to write user tutorials such as how to ask good questions and MathJax basic tutorial and quick reference and posted them on the meta site.

4.3.8. Contradictions

In Activity Theory, *Contradictions* refer to historically accumulated tensions or instabilities within or between activity systems, playing a central role in changing, developing, and learning the activities. Contradictions may exist within each component of an activity system, occur between components of the activity system, happen between different developmental phrases of the activity, and appear between different but interconnected activity systems (Engeström, 1990).

**Table 4.12. Contradictions Identified By Interviews (* Means This Contradiction Was Only Reported By Interviewees of Mathematics SE)**

<table>
<thead>
<tr>
<th>Contradictions between Object and Tool</th>
<th>Latex display, direct communication, front page design, duplicated questions*, question filtering*, question rediscovery*, question migration*, search system, user analysis*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contradictions between Object and Rule</td>
<td>question close-open war*, question closing process, reputation hunting, incentive system, user education*, personal attacks*, conflicts between moderators*</td>
</tr>
<tr>
<td>Contradictions between Object and Division of Labor</td>
<td>moderator qualification*, closing question enthusiasm of quality manager*, lack of content creators with enough domain specific knowledge</td>
</tr>
<tr>
<td>Contradictions between Object</td>
<td>researcher group and educator/student groups</td>
</tr>
</tbody>
</table>
The following sections provide examples of contradictions in Economics SE or Mathematics SE. The first three categories are contradictions at the second level (contradictions that arise between the components of an activity system). There are also primary contradictions (inner contradictions of each of the components of an activity system) within the communities.

**Contradictions between object and tool** refer to the cases where inabilities of a tool prevent the objective of an activity from being met. The interview data analysis identified nine types of contradictions between objective and tool:

(a) **Latex display**: when users were writing long answers, the embedded Latex renderer could cause a lot of slowdown and cannot scroll the output. As one interviewee of Economics SE (E-P8) explained: “When you are writing a long post, it automatically displays the Latex of your post below, if you use Mathjax. But you can’t scroll the output. So you can either see what you are writing, or scroll down to see what the end results of what you have written, but not both.”

(b) **direct communication**: there is no way to pin a particular user to invite him/her to answer questions;

(c) **front page design**: very few questions are allowed to stay on the front page. Thus, when users come to the site, it is highly likely they are unable to identify any interesting question.

(d) **duplicated questions**: there is no way to identify duplicated questions or answers, especially when the content contains math formulas. As one moderator of Mathematics SE (M-P2) explained: “There is no good way in identifying duplicated questions or answers. This gets worse every August when you have several thousands of new students entering to the MSE and taking calculus 1 and 2, and ask all the same calculus 1 questions every year. It would be great if we are better at identifying this has been asked and answered there. On the other hand, people are very sad when their questions were asked and closed as duplicate. It feels like I am not welcome
Search engines don’t index Latex, so the actual rates of identifying duplicates are really bad. What this also means is that we have lots of duplicate efforts. If I look up something like a proof of the Euclidean algorithm, I would find a hundred essentially identical answers. Every once a while I would try to close some of the threads which are duplicated, because you don’t want people google to find out that there exists an OK answer, but are wondering whether there exists a great answer. In contrast to someone who can understand one of these answers, but happen to find a duplicate which does not have an understandable answer to them. This make it sprawl, and make the site less useful to later people.”

(e) question filtering: the system was unable to filter out questions users may not have interest to answer. As one interviewee of Mathematics SE (M-P13) stated: “I would like them to add more features for filtering questions. Right now, they have added the ‘interesting’ tab that allows you to look only at the questions that the software guesses you might find interesting, but it is not enough. It needs to be easier to filter out questions that you might not be able to or want to answer.”

(f) question rediscovery: newly posted questions had a very short time period to be listed on the front page, thus those questions got ignored very soon and was unable to be rediscovered. As one interviewee of Mathematics SE (M-P15) stated: “when new users ask questions, those questions will stay on the front page for just a couple of minutes, because we have such a high flow of questions. Once the question get ignored, it really difficult to get interest again. If someone picks a question in the first minute of its existence, then the question is likely to get a good answer, but otherwise, it’s very likely to just sit on the site without any attention. One idea might be to have those old questions promoted by an automatic reward placed system. But I don’t know, because there are some questions can be answered well, and some other questions really need to be
Another interviewee (M-P6) explained why upvotes and bounties were inefficient to facilitate question discovery: “Right now, the only ways to get visibility are upvotes and bounties. Upvotes are not effective because you only have one, and large numbers of upvotes normally only come when users click on the question from other Stack Exchange sites (this is through something called the Hot Network Questions list). Bounties are not usually effective at all, they are usually ignored by most users.”

(g) question migration: there is no direct method to migrate questions to other sites in the Stack Exchange network, like Math Overflow, Mathematica SE, Cross Validated, Physics SE, etc.

(h) search system: the search system has issues in managing Latex strings, thus if users search for math formulas, it does not work that well.

(i) user analysis: The statistic report didn’t offer information regarding what percentage of user in just answering question, or just asking questions, or a mix of both. As one moderator of Mathematics SE (M-P8) stated: “we want to know the ratio indicating different people, questioners and answerers. In Mathematics SE, probably 75% users ask more than they answer, that means we expect every post get answered, we need to encourage those 25% users answer at least three times than they ask.”

Contradictions between object and rule refer to cases where specific rules create barriers that inhibit the subject from meeting his/her objective. The interview data analysis identified seven types of contradictions between objective and rule:

(a) Question close-open war refers to the contradiction between the rule of close/reopen question and the objective of gaining high quality content. As one moderator of Mathematics SE (M-P17) explained: “Usually, different users just have different opinions and choose to close different questions: some users never cast any close votes, while other users frequently vote to
close any question that does not show enough effort or does not provide enough context. This leads to close/open wars (the question is closed and then reopened and then closed again, etc.), and moderation has no general process to follow because the community is completely divided about whether the question should be open. We are not everywhere and, when summoned to the scene of such a dispute, we rarely have options other than resorting to peace-forcing measures.”

(b) Question closing process refers to the contradiction between the rule of closing question and the objective of facilitating communication among users. The current question closing process does not require voters to explain i. As one interviewee of Economics SE (E-P3) stated:

“Sometimes when I answered a question, when I finished editing, the question got closed so I was not able to submit the answer anymore. That’s a little bit annoying. It might be better to make a change to closing vote policy---if everyone vote to close a question must leave a relatively detailed comment, why they close it, what they would like it changes to, other than just click the button to say off topic, which is very unhelpful to the users. Also give users a few minutes before they actually make changes before the question gets closed.”

(c) Reputation hunting. The reputation-based privilege system was designed to encourage content creation and editing—by posting useful questions and answers, users can earn reputation points that control what they can do on the site. However, since reputation points have no relation with question difficulty, many users game the rule by answering lots of easy questions that do not have long-last value. As one formal moderator of Mathematics SE (M-P19) stated:

“There was a sense of ‘grubbing for reputation points’ I was trying to avoid. The reputation system came to bother me, effectively because against my wish it became more compelling than the simple pleasure of writing good answers, of feeling I’d helped someone. This was resolved by my leaving the site. The site is a useful resource, users at all levels do stay around, if they can
stomach the fact the 'reputation point game' is dominated by those willing to pick up the low hanging fruits of calculus and below.”

(d) Incentive system. To resolve the reputation hunting contradiction, bounty was introduced to encourage answers to difficult, research oriented questions. However, compared to the effort devoted, the value of bounty is still much lower than answering many easy questions. As one interviewee of Economics SE (E-P7) stated: “What they have is the so-call bounty, users can offer certain reputation points if others answer this question. However, a very hard question may require a day of work or thinking, and the reward of answering that question is similar to answering lot of easy questions. For those answerers who just try to get much points as possible, the more efficient way to get points is to answer a brunch of easy questions. So a lot of times even if with the bounty, it seems it’s not worth the effort.”

(e) User education. Although users are encouraged to check the meta site and other user tutorials before posting questions, there is no official policy to enforce such practice. Many users concentrated on asking for help and/or providing answers, and largely ignored the discussions about site policy and maintenance, even if for those issues they cared about. One moderator of Mathematics SE (M-P8) explained the dilemma they faced regarding if some level of new user training should be made mandatory: “For example we are continually fine-tuning the homework policy, but there is a largish mass of users won’t participate in policy discussions. Attempts to keep those users in check is a continuous source of bickering and disagreement. We thought about whether to ask the new users to read meta posts and the Mathjax tutorial before they post their answers. On one hand, there would be another source of friction, and that would be bad. On the other hand, it would increase a lot the quality of initial posts. The first impression of people is important for them to decide whether to continue to use this site. Immediate positive
reinforcement, they might want to come back; immediate negative reinforcement, they might choose not to come back. But I am not certain whether I think that is actually a good idea.”

(f) **Personal attack.** Violation of the be nice policy could result in content deletion, but it cannot prevent personal attacks, especially outside of the system. One interviewee of Mathematics SE (M-P5) mentioned that his senior professor received offensive emails because he once had conflicts with other community members: “I think that short-term bans should be used in cases where disagreements are taken off-site in an abusive way. I had someone send an offensive email to the senior professor in my research group because I had criticized his post on MSE; when this was brought to the attention of MSE moderators, the response was that since this had taken place offsite there was nothing that could be done.” An moderator (M-P11) also mentioned that’s also a reason why some moderators on Stack Exchange chose to be anonymous: “If you go to my profile, you can find out my website. If you go to my website, you can find out my name and email. I do moderation tasks, which involve suspending some users, or deleting some questions. And then I will essentially get hate mail from these users. I know several SE moderators anonymous for exactly this reason. If you get hate mail and live in New York, everybody can just come to find you or something.”

(g) **Fights between moderators.** Moderators have authorities to forcefully stop all actions of a user or suspend his/her account if abnormal user behavior is confirmed, however, there is no rule to follow if moderators themselves have fights. As one moderator of Mathematics (M-P2) stated: “By design moderators can overrule anything, including each other. Once two moderators ended up suspending each other, and they unsuspended themselves because they can do that. They both delete and undelete questions, and one of them actually deleted the other user, and that’s not undoable. We have to call the community team, they suspended both. They have to spend a week
to try to reinstall the deleted user. And then we have a couple of moderator short because they stopped let either of them being a moderator.”

Contradictions between object and division of labor refer to cases where the division of tasks among members of a community inhibits the objective of an activity from being met. The interview data analysis identified three contradictions between objective and division of labor: (a) moderator qualification, (b) closing question enthusiasm of quality manager, (c) lack of content creators with enough domain specific knowledge. The first two contradictions were reported only by interviewees of Mathematics SE.

(a) Moderator qualification refers to the contradiction between the capability of moderators—the division of labor—and the objective of moderating the site successfully. When casting moderator vote, users tended to evaluate candidates based on their reputations rather than moderation experience, thus elected moderators may not have the capability of moderation:

You know moderators are elective. This is sort of odd choices of phrase because almost always happens is people with the highest reputation win. People don’t pay attention to other activities on the site, say in the meta, because this is sort of indicators of evidence that people who would not be a good moderator come from. So people would just say this person has a lot of reputation so I will probably vote for him. And it happened in the past that we would have bad moderators. (M-P8)

(b) Closing question enthusiasm of quality manager refers to the contradiction between the working practice of quality manager and the objective of encouraging posting questions:

I think there is a group of people who was closing questions very quickly, they are really overzealous with closing questions. I think it’s harmful to the site. It becomes less well-coming than it used to be, and it’s a little harsh to new users. I think many times the
questions were closed and listed as off-topic, not enough context, when really just people haven’t got used to use the site yet. I personally will prefer those people can leave a comment, let the asker fix the question rather than immediately shut it down. (M-P4)

A formal moderator of Mathematics SE explained why quality managers tended to close questions very quickly:

It seems to be two accounts of people: those who are looking to quickly close questions if the questions don’t provide sufficient context, and those who want to answer the questions quickly to earn more reputation points before they get closed, because once a question gets closed, you cannot post any answer. And those people who looking to close it resist those trying to answer quickly because, I guess their thought is answering is just encouraging that sort of behavior, so they should try to keep people off from posting answers to those questions. (M-P19)

(c) Lack of content creators with enough domain specific knowledge refers to the contradiction between the number of content creators with enough domain specific knowledge and the objective of minimizing the number of unanswered questions:

Relatively fewer people have a lot of domain specific knowledge. Sometimes I looked through the automorphic form of number theory and analytic number theory tags, and answer the questions I found interesting. But many users don’t do that. So we have a much larger number of unanswered questions than we used to. It ends up affecting lots of different weird aspects of the site that you may not think about. Because more unanswered questions mean that more people will google the site, find some questions that they asked, and have not been answered, and think how useless this site is. (M-P9)

A moderator of Economics SE (E-P2) also mentioned lacking of professionals who can answer questions was a frequently-mentioned topic on Economics meta site: “A big discussion topic on
meta is a lot of users do want more professional users on the site. ‘we should have more professionals, how can we do it?’ was asked every few days.”

**Contradictions within object** refers to the cases where the conflicting of objects is fundamentally embedded within different subject groups. The interview data analysis specifically indicated that the researcher group and educator/student groups have different opinions regarding the community goal and scope, as well as how to deal with homework questions. One interviewee who identified himself as a researcher explained why he thought Mathematics SE should have a more restricted scope and minimize the number of homework questions:

There is ongoing and widespread disagreement about what kinds of questions should be considered off-topic and closed. These disagreements have generated hundreds of long debates on meta, without being really resolved. Maybe the site should be more limited in the level of the questions. It is an ambitious attempt to include everything from high school to graduate school. I am not sure but according to many the site has earned the questionable reputation of being a homework factory for calculus students and below. It’s not really intended to be a place for people to just put their homework up and ask somebody to do for them. Sometimes I or somebody else will flag those questions. I mean, questions that are very specific, about some homework exercises, will not help future users. Those questions often formatted poorly, and are often duplicates of previous questions. Then for us it is very hard to find interesting questions to answer on the site. Although some community members have tried to moderate by closing and down voting those questions, this has not been successful (it has only made it harder for new users of the site). So the site is just flooded with a lot of uninteresting questions. (M-P14)
On the other hand, those interviewees who identified themselves as educators agreed that Mathematics SE should have a different community mission with Math Overflow, and welcome homework questions that aim at learning:

There has been a lot of debate in the community about how to treat homework problems. Some people, this depends on what are users come to this site for---some of them coming from a point of view of teachers, they treat every question as an opportunity to teach something. Other users, are really just trying to demonstrate they know a lot of math. There is no rule says Mathematics SE is a community for researchers or educators, it is a community for people who want to ask and answer about math. There is nobody says one of the positions is favored over the other. So if a student posts a homework question, what happens a lot of times is one of the educators says this is a homework question and you should probably show a little bit work to tell us you are not just looking for the answer. And more to the point, an educator needs to know where the student’s head really is. Are they stuck on the problem because they don’t understand the term, the words of the problem? Or they stuck because they have some misconception? Or they stuck because of an algebra? All these can lead to different, better answers. (M-P10)

4.3.9. Skills for Participating in Stack Exchange Q&A Communities

One of the interview questions concerned the skills required to participating in Economics or Mathematics SE site. The interview data suggested a typology of eight skills: basic domain-specific knowledge, understanding the question correctly, written communication, good control of English, writing in Latex system, interpersonal and social skills, teaching skills, and adaptability. Those skills were emphasized by interviewees from both Economics SE and Mathematics SE except the teaching skills.
The most frequently mentioned skills are written communication and writing in Latex system. A retired math professor (M—P20) stated: “That’s something really hard of mathematical training as well—if you are a graduate student in Mathematics, one of the things you have to learn is mathematical English, which is not exactly the same as regular English. Lots of things in Mathematics that have very particular meanings, while in regular English things are much looser. You have to be able to say what exactly you mean.” All interviewees of both sites emphasized the ability of writing in Latex system because questions and answers didn’t type in Latex and MathJax usually seemed much more poorly.

*Interpersonal and social skills* required mental confidence, resilience, and social aptitude. As one postdoc in math (M-P7) stated: “When you first join the site you are likely to break some rules. This will attract downvotes, close votes, and/or comments that you should have done something differently, and these comments are not always kind. It can be very disheartening, and participating in the site successfully requires that you can handle this negative feedback and recover from it.” Another ‘soft skill’ was *Adaptability*, which was considered important especially for those established scholars. As one math professor (M-P13) stated: “New users face a learning curve independent from their level of mathematical sophistication. The site has developed its norms, do’s and do-not’s that are somewhat different from what they seem to have expected. So a new user needs to invest some time learning the ropes. Not all more senior mathematicians are flexible enough to get past this point. I recall having had a few surprises myself, but others have arguably had it worse.”

Teaching skill was mentioned only by interviewees of Mathematics SE, because some members emphasized the teaching aspects of the site. One university lecturer in math (M-P18) who also identified himself as an educator explained: “Math SE is kind of special, there are lots of
students there asking about their home works, they are confused about lots of things. When I come into math SE as an educator, I’m always thinking about what’s causing this question. You should have knowledge about what those difficulties are beyond the subject matter. To me it involves the same kind of skills of being a good teacher. It’s meeting people where they are.”

<table>
<thead>
<tr>
<th>Basic domain-specific knowledge</th>
<th>Economics/Mathematics subject knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding the question correctly</td>
<td>The ability to understand what’s being asked, interpret it in a reasonable way</td>
</tr>
<tr>
<td>Written communication</td>
<td>The ability to communicate ideas effectively and with clarity in written format</td>
</tr>
<tr>
<td>good control of English</td>
<td>The ability to correctly understand and write in English with correct capitalization,</td>
</tr>
<tr>
<td></td>
<td>grammar and spellings; the ability to use terminology correctly</td>
</tr>
<tr>
<td>Writing in Latex system</td>
<td>The ability to write in Latex format</td>
</tr>
<tr>
<td>Interpersonal and social skills</td>
<td>The ability to maintain mental confidence and resilience and deal with different opinions</td>
</tr>
<tr>
<td>Teaching skills*</td>
<td>The ability to understand where the question comes from and help other to develop their subject knowledge</td>
</tr>
<tr>
<td>Adaptability</td>
<td>The ability to learn and adapt themselves to the community norms</td>
</tr>
</tbody>
</table>

4.3.10. Community Success Indicator

Most interviewees mentioned they were aware of the metrics used by Stack Exchange to evaluate site status and agreed those metrics were in general reasonable and effective to reflect the potential of a site. Interviewees of Economics Stack Exchange confirmed that they tried some strategies, such as creating more traffics and posting pseudo questions, to help the site graduate from public beta. They also complained that criteria used by Stack Exchange to evaluate public beta sites were vague and the reasons why a site was kept in beta status or got closed may not directly related to its performance. As a moderator of Economics SE stated:
It used to be there were four main metrics for beta to be evaluated. But actually, that’s not exactly what they use, that’s not direct, corresponding numbers they use to decide whether a site is graduated or not. A site could still stay in beta forever. Especially now, the new policy says a site could stay in beta forever. Sometimes the administers of SE network enter in the meta of SE and update the policy. They keep it very fuzzy. They don’t want to have straight criteria because they don’t want people to just comment, and demand their sites to graduate. It’s not like there are things, if you pass you are going to graduate. It depends on their work flow, and it’s a lot of work for them to design the graphic elements of a site moving from a beta to an actual site, which has graphical identity. The ability of graduating more or less sites depend on their work flow and how much times they have to get those graphical designs done. They keep it very loose and very unclear how and when a site is going to graduate. (E-P5)

Moderators of the Mathematics SE (M-P11) provided another perspective regarding community developing strategies: “I never figure out what they [Stack Exchange management team] to decide site status, if Mathematics should move to the next stage. I did realize there were some metrics such as unanswered question number, total question number, visitors per day, but they didn’t bother me too much. I think the Mathematics site was quite healthy during beta phases—if they [the Stack Exchange management team] did use some unpublished metrics, it should meet. Actually, I agree that those metrics should not be published, at least not fully, otherwise people can game the system by posting a bunch of nonsense questions or using different IPs to create visits. This is not what we promised to our members.”

Interviewees also proposed a set of community success indicators they considered as reasonable to predict the survival chance of a social Q&A site on Stack Exchange network, including: (a) low member turnover, (b) high user expertise, (c) high user participation level, (d) diversity of
membership, (e) effective moderation system, (f) being able to provide useful information, (g) effective learning outcomes. Those indicators were emphasized by interviewees from both Economics SE and Mathematics SE except diversity of membership and learning outcomes. The most frequently-mentioned indicator was low member turnover. As some interviewees explained, if a site has a small returning user percentage and a large leaving user percentage, it means the experiences on the site are sufficiently good to make users stay. Being able to provide useful information was another frequently-mentioned indicator. Some interviewees described it as ‘signal-to-noise ratio’, which not only represented the usefulness of content but also the effectiveness of getting useful content.

Diversity of membership and learning outcomes were only mentioned by interviewees of Mathematics SE partly due to its mixed scope and diverse sub-communities. As one interviewee (M-P16) mentioned, the diversity of membership could retain most of traffic and more advanced user groups: “the diversity is there in that the more advanced (grad school level) sub-communities are doing ok. I am uncertain whether such sub-communities did even better when the site was relatively new (and to a greater extent also populated by visitors from MathOverflow). I am uncertain whether we can keep it that way without significantly culling the flood of lower level questions. On the other hand that’s most of traffic comes from. Optimizing the site to accommodate all (or most) of the wishes of the contributors is not easy.” Users who considered themselves as educator or student emphasized learning outcomes should be used as criteria to evaluate the success of Mathematics SE, although it was very difficult to measure:

“It’s kind of like how do you assess an undergraduate program is successful or not. That’s a large question. I will have difficulty to measure how it is beneficial to me. I have learnt a huge
amount by interactions on the site, and I’m not sure if there is any way for the site to measure those things.”

Besides those five metrics (question per day, percentage of answered question, answer ratio per question, visits per day, numbers of high-reputation user and total user) published by Stack Exchange, table 4.15 shows a set of metrics interviewees considered effective to evaluate the status of a social Q&A site.

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Question-related</th>
<th>Answer-related</th>
<th>User-related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of question, Number of question has many votes, Number of duplicate question, Number of close question, Answered question per day, Ratio of answered to unanswered questions, Average number of votes per question, Average number of question per user</td>
<td>Number of answer, Number of answer has many votes average, Number of votes per answer, Average number of answer per user</td>
<td>Average user reputation, Number of new user per month, Number of old user remain active, Percentage of returning user, User participation time</td>
<td></td>
</tr>
</tbody>
</table>

4.3.11. Criteria and Measurements of High-quality Questions and Answers

Besides community success indicators, the interview data analysis also identified a set of criteria and measurements(metrics) interviewees proposed to predict high-quality questions and answers. The most frequently mentioned criteria of high-quality questions were clear definition, details, show effort, and inspirational. Clear definition refers to the extent to which the representation of a question is precise and well-defined with all relevant concepts. As one interviewee (M-P6) stated: “A high-quality question should state clearly what the asker want, what they have done in an attempt to solve the problem already. Any terms or notations used that are not very well-known should be clearly defined, or at least a link to a free online source providing the definitions should be provided. Questions don’t have to be self-contained (e.g. a question on algebraic geometry shouldn’t have to define “cohomology”) but they should be self-contained
‘apart from fundamental content.’” Details refers to the extent to which the amount of information in the question is appropriate. Most interviewees agreed that a high-quality question should provide context for the question, explain what the asker has already tried and what the motivation is, and give enough background information that answerers know what level to write a response. Show effort refers to the amount of work involved in solving the problem. All interviewees stated they would not answer those questions that include routine textbook exercises and expected askers to include some efforts in their questions so it would not appear to be a homework solving site: “Ideally askers should be putting in at least some work of their own, showing some kind of effort, and if they just stuck on some part of the process or if they need a hint, then you just provide that. ‘This is what I have done and these are some resources I have used to get there’, those are great—since they let you know exactly where to meet them. A high-quality question is one that is well-researched. The asker has taken the time to try solving it, and to do a Google search and read some basic textbooks before asking. Conversely, poor questions include routine textbook exercises, questions where the asker is clearly out of their depth because they’re in a course for which they’re substantially unprepared.” Inspirational refers to the extent to which the question is beneficial and provides new thoughts from its use. This criterion was emphasized by those users who identified themselves as researchers. As one interviewee of Mathematics SE (M-P14) explained: “A high-quality question often captures a distinctive phenomenon in a way likely to be useful to many people over extended time. I think the crucial property of a good question is that ‘progress can be made’: there should be a sense that meaningful forward movement can be accomplished in the answers, even if there will not be a unique right answer.”
The most frequently mentioned of high-quality answers were **relevance** (*addressing the real question*), **understandability**, **writing style**, and **enlightening**. Relevance refers to the extent to which the answer is applicable for question in hand. As one interviewee of Mathematics SE explained: “A good answer should answer the question, obviously to the extend it’s possible to answer the question. Sometimes the correct answer is we don’t know, and it should point out why we don’t know. A good answer also often answer the real question the asker did not overtly ask. Sometimes people really ask something that’s not really literally what they mean, but what they really want is something different. You have sometimes see what’s really behind the question.”

**Understandability** refers to the extent to which the answer is easily comprehended. As one interviewee of Economics SE (E-P7) stated: “For a high-quality answer, it’s one meets the person where they are. It should be aimed at roughly the asker’s level of understanding, and treat the question under the assumption that other users of comparable mastery will also ask it or something like it. Paying particular attention to the asker’s level of expertise is important.”

**Writing style** refers to the unique characteristics of word/symbol choice and sentence fluency present in the answer. All interviewees agreed that a good answer should be well-written and documented with clear English and good use of LaTeX. A good answer should also try to use the same notation and terminology as in the question, unless it is clearly disadvantageous to do so; and in this latter case clear definitions should be provided. **Enlightening** refers to how much mathematical/Economical value an answer can provide. As one interviewee of Mathematics SE (M-P13) mentioned: “I like those answers that add a totally new angle to look at a question. Using tools from an unexpected area of math make my eyes light up. I think a good answer should take the point of view of teaching and transferring skills or techniques, rather than just a simple solution. The answers I like explain the background and steps, and might even give more
context and further ideas. A good answer may provide further detail or further reading or external links for those who may be interested in learning more.”

| Table 4.15. Evaluation Criteria and Measurements of High Quality Questions and Answers Identified From Interviews |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Criteria                                                                                     | Measurements                                      |
| High-quality question                                                                       | Clear definition, Conciseness, Usefulness, Novelty, Objectivity, Refer to external resources, Writing style, Details, Show effort, Inspirational (have board interest and impact) | Number of image                                 |
| High-quality answer                                                                        | Relevance (addressing the real question), Clarity, Completeness, Conciseness, Understandability, Objectivity, Writing style, Refer to external resources, Details, Educational, Enlightening | Number of click/view, Upvote count, Number of error in writing |

4.4. Conclusion

This chapter presents findings attached from three research methods: content analysis of question-answering threads and site management threads of Economics Stack Exchange, social network analysis of user interactions of two sites, and semi-structured interviews with moderators and ordinary users of two sites. The findings from content analysis and semi-structured interviews were further divided into subsections based on the concepts of Activity, including activities, communities, division of labor, tools, rules, contradictions, and skills. Section 4.3.10 and section 4.3.11 also reported findings of community success indicators and criteria/measurements of high-quality questions and answers. Chapter 5 will present discussions on each of the research questions and sub-questions, relating the findings of this study to the literature.
CHAPTER 5

DISCUSSION

This chapter discusses findings presented in Chapter 4 in light of the research questions, providing a synthetic view of the findings attained from three different research methods. This chapter also includes implications of the findings in relation to the literature and discussion of potential future research. Based on the analysis of contradictions within and between activity systems of those two Q&A communities, suggestions were made to designers of existing peer production communities as well as individuals, groups, and organizations who intend to start, maintain, and/or grow a new community.

5.1. Activities on Economics Stack Exchange/Mathematics Stack Exchange

The first research question focused on the activities on Economics Stack Exchange/Mathematics Stack Exchange at their startup stage (from the time they were proposed to the time they graduated from or had been closed in public beta phase). According to Activity Theory (Engeström, 1990; Leont'ev, 1978), activity refers to a complex system of related elements, including subject, object, community, division of labor, rules, tools, and outcome. Activities on Economics Stack Exchange or Mathematics Stack Exchange could vary by subject, community, and object. Figure 5.1 and 5.2 show the activity systems of the Economics Stack Exchange and Mathematics Stack Exchange. Members of Economics Stack Exchange and Mathematics Exchange were dedicated to developing and maintaining an online knowledge repository and put lots of efforts into activities of content creation, meta-content work, and voting up/down. Comparing to those of Economics Stack Exchange, users of Mathematics Stack Exchange devoted themselves to various supporting activities including quality assurance, user management, tool development, promotion, and communication. For those activities shared by
two sites, the Mathematics site also have more specific, diverse subcategories. For example, in content organization activities, users of the Mathematics site not only created, deleted, assigned, and removed tags, but also did other meta-content work such as closing duplicate questions and migrating questions. Table 5.1 shows categories and subcategories of activities only appeared on the Mathematics Stack Exchange. Besides posting questions and answers, a variety of community support work became even more important to the health of a social Q&A community on Stack Exchange network, confirming previous studies (Kriplean, Beschastnikh, & McDonald, 2008; Morgan, Bouterse, Walls, & Stierch, 2013). The following sections will present discussions on those community support activities.

Figure 5.1. Activity System of the Economics Stack Exchange
Figure 5.2. Activity System of the Mathematics Stack Exchange

Table 5.1. Activities Only Appeared on the Mathematics Stack Exchange

<table>
<thead>
<tr>
<th>Category</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content Development</td>
<td>Review suggested edits; Post bounties to invite answers</td>
</tr>
<tr>
<td>Content Organization</td>
<td>Close duplicate questions; Migrate questions</td>
</tr>
<tr>
<td>Quality Assurance</td>
<td>Flag spams or abusive posts; Track votes</td>
</tr>
<tr>
<td>User Management</td>
<td>Educate new users; Regulate user behaviors; Mediate conflicts; Access user databases; Ban IP address; Suspend user account</td>
</tr>
<tr>
<td>Tool Development</td>
<td>Develop moderation tools; Write and update user tutorials; Request features; Report bugs</td>
</tr>
<tr>
<td>Communication</td>
<td>Talk to other users in Stack Exchange chat rooms</td>
</tr>
<tr>
<td>Promotion</td>
<td>Maintain site blogs; Promote site using other platforms</td>
</tr>
<tr>
<td>Moderation</td>
<td>Lock posts; Communicate with SE management team; Edit script code</td>
</tr>
</tbody>
</table>

**Quality Assurance**: compared to those of Economics Stack Exchange, users of Mathematics Stack Exchange spent much more time on editing other users’ questions and answers, flagging spams and abusive posts, closing low-quality posts, and discussing if a closed question should be
reopened. Previous studies have shown collaborative editing and collaborative peer review can increase both the quantity and quality of contributions to a peer production community while reducing antisocial behavior (Cosley, Frankowski, Kiesler, Terveen, & Riedl, 2005; Dabbish, Stuart, Tsay, & Herbsleb, 2012; Kittur & Kraut, 2008; Li, Zhu, Lu, Ding, & Gu, 2015), which have been confirmed by findings of this study. It has been widely believed that Wikipedia’s success in producing articles with high quality is largely attributed to the open collaboration model that allows any person to participate in the editing, and the benefits of adopting collaborative editing to social Q&A outweigh its potential drawbacks. Findings of this study also suggested that users of the successful Q&A community utilized the collaborative editing features more fully and frequently. For example, both content analysis and interviews data analysis have identified that users of Mathematics Stack Exchange treated spam, rude, or abusive flags very seriously and spent lots of time to flag those posts and decided how to deal with those flags, while no such flagging activities have been identified from Economics Stack Exchange. According to the collective effort model (CEM) (Karau & Williams, 1993, 2001), collaborative editing can strengthen the link between effort and contribution to the group’s performance, if people believe others will improve on their contributions. Members of Mathematics Stack Exchange who are afraid of making mistakes might be more willing to contribute if they know someone will edit their work.

Activities related to collaborative peer review mechanism have also been emphasized on Mathematics Stack Exchange. After a question or an answer was posted, users of Mathematics Stack review the post and take appropriate actions if the post does not meet quality requirement or violates community policies. The utilization of collaborative peer review mechanism may do more than just keep people in line but also discourage low-quality contributions such as spams.
and vandalisms. A key component in the motivation of spammers and trolls is that by posting advertisements or inflammatory messages (individual performance), they get responses (individual outcome). The collective effort model suggests that reducing the link between posting a message and getting responses should reduce spammers’ and trolls’ motivation to make low-quality contributions. Tactics like quick checking and editing that remove the link between an individual’s contribution and the group’s performance should reduce vandals’ motivation. Collaborative peer review also makes the connection between a member’s efforts and their value to the group’s performance more salient, which the CEM suggests will increase motivation to contribute.

Mathematics Stack Exchange also used some additional tactics to ensure the collaborative editing and peer review were effectively enforced and the potential harm was minimized. These tactics might be useful for practitioners who want to replicate the collaborative editing features to their own systems. First, Mathematics Stack Exchange relied on the experienced users to moderate the collaborative editing activities--although any user can suggest edits, only users with more than 2,000 reputation points can review and approve the suggested edits. It is important to have experienced users to judge the appropriateness of edits rather than immediately applying them, which prevents the harmful effects of spamming edits and encourages more cautious edits. Second, Mathematics Stack Exchange made efforts to communicate their policies to the community. Mathematics Stack Exchange made the pages of “why can people edit my post” and “how does editing work” explicit in the help center: pages which were accessible and salient to every user. Third, Mathematics Stack Exchange allowed users to express their opinions and present their arguments on meta, which pacified the agitated users and lessens the potential harmful effects of any community decision.
User Management: activities of user management, such as educating new users, regulating user behaviors, mediating conflicts among users, were only identified on Mathematics Stack Exchange. User education was another approach to control content quality and create initial positive interactions that could help retain new users. Moderators and high reputation users composed and updated user tutorials regularly, posted those tutorials on meta site, and posted links of user tutorials in comments. They also communicated with new users by comments and linked meta site threads to main site threads to explain why certain community decisions were made. Similar to previous studies (Mahmood, Burn, & Gemoets, 2000; Skok & Legge, 2002; Sumner, 2000), the current study confirmed that user training and education can be important for community success. Through meta discussion and user tutorials, new users can gather greater knowledge and understanding of the system, potentially increasing their confidence in using the site thus affecting their continuous participation. By introducing community norms to new users, they may contribute more effective to the community, thus the Stack Exchange network should revise the current privilege system to make user education (e.g. reading user tutorial) mandatory. Similar to previous studies (Lampe & Resnick, 2004), findings of the current study suggested that user satisfaction and behaviors of new community members could be affected by the moderation feedback they received and comments replied to content they posted. Both content analysis of meta site discussion and interviews revealed that abnormal behaviors and user conflicts were resolved via flagging and reviewing flags in certain review queues. The process usually begins when one member flags a certain post and states the concern or dissatisfaction of the owner of the post. This post then enters certain review queues that addressing abnormal behaviors and user conflicts. Those who review this particular issue then write responses and decide what action should be taken (e.g. deleting or locking the content, locking the owner’s
account, doing nothing, etc.). If the problem persists, the community moderators are tasked with
the responsibility of resolving the matter. A wide variety of informal user management or
conflict resolution strategies were applied in the process, including posting guidelines and advice
about decision-making in comments, establishing conversation for community discussions aimed
at finding a group consensus on meta site, and in extreme cases, organizing private meetings of
moderators to discussion a certain case. Similar to quality assurance activities, the utilization of
comments, meta site, and chat rooms pacified the agitated users: people would consider the
procedure fair if they have control over the presentation of their arguments and there are
sufficient opportunities to present their cases. This could probably explain the fact that although
there were complains related to collaborative editing, peer preview, user behavior regulation,
conflict resolving, and other issues posted on meta site, but little negative effects on users’ actual
contributions were reported from interviewees because the opportunity to complain itself might
already allay their anger.

**Tool Development:** the use of support technologies and tools has been proven to supplement the
capabilities and productivity of a system (Aladwani, 2002; Wixom & Watson, 2000). Similar to
user management, activities of tool and feature development were only identified on
Mathematics Stack Exchange. moderators and high-reputation members of Mathematics Stack
Exchange devoted lots of efforts to write web apps and scripts for content editing, searching and
browsing, moderation, and user education. (see section 4.3.6). Some of those tools were
published for public use or even adopted by Stack Exchange management team. This is a new
category of community support activity that hasn’t been reported by previous studies. The CEM
suggests that individual’s motivations to contribute to a collective task/group work are positively
correlated to the extent to which the group performance will be instrumental in obtaining a
valued group outcome and individual’s perceived value of the outcome of the task. Thus activities of tool development that help community members reduce their efforts to perform certain tasks could motivate them to contribute. For example, giving moderators a tool like automatic low-quality post detector could reduce their efforts of identifying and reviewing low-quality content thus increase their motivations to preform quality assurance tasks. The CEM also suggests that helping people achieve better performance for a given effort will motivate them to contribute. For example, content editing tools that help user copy comments, correct misspellings, format link to a webpage or a tweet, convert Lyx-produced latex markup to markdown/mathjax could motivate them to make more contributions since those tools helped people achieve better performance for a given effort. The Stack Exchange network could either add cross-community tools/features to support content editing, searching, communication, moderation, and user education, or use reward/reputation system to encourage tool/feature development by members of individual sites.

**Communication:** effective interaction between members in a peer production community can facilitate the alignment of goals and expectations, achieve mutual understanding, and encourage effective collaboration. Communication between users in a Q&A community on Stack Exchange can be informal or formal, direct or indirect, one-way or two-way. Most communications on Economics Stack Exchange and Mathematics Stack Exchange occurred on meta sites (formal, both one-way and two-way). The function of meta sites is similar to the discussion pages (talks) on Wikipedia, that are used by editors to exchange opinions about potential changes, by administrators to communicate management information, and by those outside the article’s editorial group to ask questions or solicit assistance for other articles. Different user groups used the meta site in a variety of ways. Ordinary users can communicate to moderators and high
reputation users, asking questions about how the community works, or about policies and why certain community decisions were made; moderators can explain the policy system, post site status analysis or user tutorials, or call for participations; all community members can communicate with the Stack Exchange management team, posting bugs, suggesting improvements, or proposing new features; the Stack Exchange management team can communicate with the whole community, soliciting feedback on new ideas or features, or announcing updates of policies that affect the whole network. In this sense communication via meta discussion is influential through the role it plays in facilitating information exchange, mutual understanding and collaboration, and in identifying and resolving conflicts (Keil, Tiwana, & Bush, 2002; Oz & Sosik, 2000). This form of communication was effective in supporting community development—the successful Mathematics Stack Exchange had significantly better meta conversations both in quality and quantity. Users of Mathematics Stack Exchange also had the option to invite users to discuss in a chat room (informal, two-way). Users may feel more comfortable to express their opinions and presents their arguments in a safe space, without showing the whole conversation to public. The effectiveness of such direct communication could have positive impact on conflict resolving and work coordination and minimize the potential harm, due to the “fair process effect” or the “voice effects” (Colquitt, Conlon, Wesson, Porter, & Ng, 2001) in group psychology. If users who have been involved in a certain community decision have an opportunity to express their opinions and learn the rationale behind the decision and the standard they are judged, they are more likely to accept the decision and negative effects of the decision can be controlled. The Stack Exchange network should customize reputation systems on individual sites to encourage more utilization of the meta site and chat rooms.
Promotion: user of both Economics Stack Exchange and Mathematics Stack Exchange were continued to invite users to their site via in-site sharing feature, which has been identified in both content analysis and interviews. Besides that, users of Mathematics Stack Exchange also maintained a blog to promote the site and advertising the site on other platforms, ranging from social networking sites such as Twitter and Facebook to internal discussion boards and mailing lists. User recruitment via personal network in daily life was reported to be more effective than any other channels and recruiting from social network sites was least effective. This is consistent with previous studies in two aspects: (a) interpersonal and word of mouth recruiting is more effective than mass communication (Montgomery, 2001; Trusov et al., 2009; Van Hoye & Lievens, 2009); (b) recruiting new members informally through their connections with existing members are more effective than any message directly from the community (Fogg & Eckles, 2007).

Meta Discussion: similar to the talk pages on Wikipedia, meta sites on Stack Exchange, which allow for text-based interaction and direct exchanges among Stack Exchange management team, moderators, and other users, help guide and control open content creation and community governance. Content analysis of meta site discussion identified 14 categories with 49 subcategories of site management discussion topics (section 4.1.4), and most discussion categories were confirmed in interviews. The most frequently occurring discussion categories on the Economics meta site were discussions about the site’s scope definition. The community struggled with the following: defining an optimal scope definition for the site; developing strategies to recruit new members and to increase member participation; generating content; promoting the site; intervening effectively to ensure the quality of questions and answers; educating and enculturating new
members and users; and fighting off malicious agents (e.g., trolls). Meta discussions showed ongoing discussions both in the private beta and the public beta phases on whether to restrict the scope of the site to high levels, graduate questions (to recruit and retain experts) or whether to allow lay, normative, and homework type questions as well.

Identifying an optimal scope for a community’s site at a particular phase of the community’s lifecycle is essential to successfully jumpstart and/or grow the community. One highly-viewed discussion thread stated, “A popular site is likely to be less expert. An expert site is likely to be less popular. Of course, the two approaches don't have to be exclusive, but it does require a more tolerant approach ... always difficult on the anonymous interwebs. I'd suggest aggressive revision of normative or poorly phrased questions rather than deletion. I'd also move for deletion of all insults and flames. Keep comments on topic and the approach respectful.” In the private beta phase the founders of the Economics site chose a narrow scope for the site limiting it to advanced, graduate level questions, while more general, basic level questions could be allowed once the site entered public beta. They were concerned that a broader or ambiguous scope would encourage low quality and/or simple questions and discourage experts from joining the community during the community’s early building stage.

This strategy was also partially influenced by Stack Exchange’s policy which requires a site in its private beta phase to have a certain number of highly rated questions as well as a certain number of members who had achieved high reputation levels in Stack Exchange. As one thread suggested, the site scope should be different in private beta and public beta phases to strategically fit the criteria set by Stack Exchange, “I think it may be unnecessarily putting people off, and the site description now does not accurately reflect the range of questions we’ve had. We’ve accepted and answered quite a lot of questions that are from a more basic level than
graduate level. We did discuss this during the private beta, and there were very good reasons for keeping it to a high level during the private beta. But we're not in private beta any more, we're trying to get out of beta and into the mainstream of Stack Exchange sites. We discussed it again in Nov 2011 and the feeling seemed to be that we'd be more open to more basic questions, as long as they were, or could be edited into, meaningful non-normative questions.” while providing access to a large collection of high quality content can help to jumpstart an online peer production community, elite members who joined the site from very beginning may not buy into it, as they stated in interviews—most interviewees from the Economics insisted the site should emphasize the research aspect. This is similar to findings from open source software development research—while large and multi projects could attract more users, they are more likely to have high complexity and high task interdependence, need to be redefined, take longer to complete, require more resources, and involve increased lines of communication and potential conflicts, thus have less chance to succeed (Schmidt et al., 2001; Yetton et al., 2000). Empirical findings also suggested excessively large project scope, changing scope or objectives, unclear goals or objectives, lack of agreement on goals or objectives among interested parties elusive goals that emerge and change as the project proceeds could have negative effect on project outcomes (Aladwani, 2002; Barry & Lang, 2003; Kim & Peterson, 2003; Peterson et al., 2002; Somers & Nelson, 2001).

The most frequently occurring categories in the Mathematics meta were still site scope definition and community governance, but new subcategories show the conceptual level and more systematical discussion of the community objectives, as well as clearer social role assignments and more interactions between moderators/high-reputation users and other community members, compared to those in the Economics meta. Discussions and debates about the site goal and target
users helped form the consensus on site scope among community members, especially regarding how to deal with homework questions on the main site, “…But in mathematics, the point of solving problems (esp. at this level) is not the answer but, rather, the learning experience - which often provides new insights. Indeed, in mathematics textbooks, the questions are explicitly designed to provide certain types of learning experiences, which is not the case for questions on most other SE sites. Unfortunately many students don’t yet have the experience to realize how important it is to earnestly practice their problem solving skills on these well-crafted problems. Hopefully we can encourage them not to use this site in a way that robs them of these essential learning experiences”. The negotiations regarding community scope also helped users understand other users’ demands thus had more tolerance to those contents they may not prefer. For example, users who identified themselves as researchers on Mathematics Stack Exchange didn’t like homework questions, but they could at least learn why educators and students emphasized the teaching and learning aspects of Mathematics Stack Exchange. It could also lead users to feel ownership of the community, and thus commitment to it. Interviewees of the Mathematics Stack Exchange also confirmed that discussions on meta site made the community to set a mixed-topic scope and use tags to create separate systems for users with different objectives. Previous research highlighted the importance of communication channel and mutual understanding between community members to community success (Akkermans & van Helden 2002; Butler, 2003; Butler & Fitzgerald, 2001). For example, in OSS communities, users and developers often use different terminology and have different frames of reference. Thus it is important to provide a forum for interaction and communication between users and other groups, in particular developers. Such interaction is perceived to enable community members to articulate their interests, objectives, and needs; to facilitate the mutual exchange of views and
expectations, improving user-developer understanding; and to assist in constructive conflict resolution (Markus & Mao, 2004). On Math meta site, discussions and disputes about closed questions provide additional channels to mediate conflicted opinions regarding specific question types and were expected to serve as archival records for new incomers, thus the scope identifying work would not be a back-and-forth process.

Compared to the Economics meta, the community governance related discussions in Mathematics meta were more diverse, the community members tried to develop a more extensive policy system to govern areas ranging from the process of becoming a moderator to what constitutes plagiarism, to methods for managing conflict and consensus building. Direct communication between members not only helped produce policy content and arrive at consensus, but also provided opportunities for members to interact, define roles and use power relationships, which are important features of group health. Some unique discussion topics that didn’t show in the Economics site included: (1) community structure, including what leadership roles are available to community members, how are people selected for those roles, and what privileges and responsibilities do people in these roles have; (2) behavioral expectations, including what types of user behaviors are acceptable or unacceptable and how the rules are enforced, (3) dispute resolution, including how violations of policy can be punished. Members of Mathematics showed more collaborative actions and dispositions; 4) user education, including how to write user tutorials and implement informal mentoring between “old-timers” and “newcomers”; (5) design innovation, including design suggestions for front-page/dashboard and editing tool. The CEM suggested that reducing the effort needed to contribute is an effective strategy for convincing people to make more contributions. For example, developing and testing editing tools of mathematical formulas was expected to facilitate more content creation.
Similarly, a well-designed site front page/dashboard that provides navigation convenience
(include site statistics and links to FAQ, unanswered questions, community wikis, etc.) could
reduce members’ mental workload thus increasing their willingness to stay and make
contributions to the site. All those unique discussion topics came with related actions. For
example, members of the Mathematics site wrote the behavioral expectations into user tutorials
and posted them on meta. They also communicated with the Stack Exchange management team
regularly to give feedbacks about whether and how explicit rules should be updated.

5.1.1. Subject

Research question 1.1 asks about subjects participating in activities of Economics Stack
Exchange and Mathematics Stack Exchange. Subject in Activity Theory refers to a people work
as part of a community to achieve the object. There were three subject groups identified from the
interview data analysis, including researcher, educator, and student, and the latter two were only
reported by interviewees of Mathematics Stack Exchange. Members of Economics Stack
Exchange shared the same community goal—to build a Q&A site for at least graduate-level
questions in economics, thus researcher was the only subject group in Economics. This was
consistent with the tight topical focus of Economics Stack Exchange. Compared to the
researcher group, the educator group emphasized the teaching aspect of a social Q&A site and
focused on helping others to learn, sharing teaching resources, practicing teaching skills; the
student group used the site as a study tool to solve problem in their studies, find interesting
questions, or improve understanding of certain concepts. Thus the educator and student group
had different opinions with the research group regarding the community scope and goal, which is
part of the reason why Mathematics Stack Exchange set a mix-topic scope and allowed some
ambiguity about the scope of the community. One moderator explained that although those three
groups were not fully satisfied with such decision, they were still able to achieve their objectives to a certain extent using Stack Exchange embedded tag system and self-developed question filters. Some ambiguity about the eventual scope of the community may be beneficial because the activity of negotiating the scope, especially through explicit meta-discussion about it, can lead the community members understand other people’s opinions and feel ownership of the community thus commit to it.

Previous literature suggested that the potential for conflict increases as the number and diversity of participants involved increases, and the presence and intensity of conflict and disagreement between various groups can adversely impact the community outcomes (Keil et al., 2002; Pan, 2005). Findings in this study instead suggested conflicts, even in community objectives, can sometimes have a positive effect if it encourages meaningful and constructive debate among community members. The participation of various groups in systems development has been suggested as a way of reducing potential conflict in projects. The rationale for this position is the increased level of mutual understanding between different sub-communities through their working together or the increased sense of ownership and control engendered through their involvement. The Stack Exchange network should emphasize communication as a dimension of user participation and customize the reputation system to encourage it if there are more than one subject groups with different objectives exist.

5.1.2. Motivation

Interview data analysis suggested a mix of intrinsic and extrinsic motivations drove participation on Economics Stack Exchange and Mathematics Stack Exchange. Intrinsic motivations such as helping others, recreation, sharing knowledge, and adherence to the principles of peer production, were mentioned by interviewees form both sites. One intrinsic motivation that hasn’t
been reported in previous studies was *challenge him/herself with math research problems*. Such intellectual stimulation is similar to the concept of internal self-concept proposed by Yang and Lai (2010), which drives individuals to pursue an activity that meets their inherent standards. Users of Mathematics Stack Exchange also reported more diverse extrinsic motivations. According to the concept of self-efficacy, when individuals determine that behaviors meet their internal standards and then receive positive feedback from performing the behavior, they feel confident in their competencies (Bandura, 1986). Previous research showed that self-efficacy positively correlates with knowledge contribution to an organization (Cabrera et al., 2006, Kankanhalli et al., 2005). Lin (2007) further suggested that employees with high self-efficacy tend to have strong intention to share knowledge within an organization. Hsu et al. (2007) also empirically demonstrated that self-efficacy is essential for inducing individuals to participate and share knowledge in online communities.

Similar to findings of previous studies (Hars & Ou, 2001; Wasko & Faraj, 2005), users may also value reputation or badges because these rewards can be transformed into social recognition, for example, self-marketing for PhD students or postdocs to demonstrate their teaching skills. However, most interviewees emphasized the practical benefits such as learning opportunities, resources, and feedbacks they received as the most important incentives drove they to keep on participating in Mathematics Stack Exchange. For example, interviewees mentioned they used Mathematics Stack Exchange to *improve understanding of course contents, learn new concepts, practice written or teaching skills*, and *look for example questions used in work*. Previous studies usually emphasized rewards earned when performing an activity such as gift or social recognition (Butler, Sproull, Kiesler, & Kraut, 2002; Chan, Bhandar, Oh, & Chan, 2004; Hall & Graham, 2004; Tedjmulia, Dean, Olsen, & Albrecht, 2005), while in this study the desire of self-
development and perceptions of the quality of the knowledge repository were leading extrinsic motivations of self-reported participation. Besides individual incentives, findings of this study also confirmed the importance of the initial period of socialization in peer production communities (Choi, Alexander, Kraut, & Levine, 2010; Morgan et al., 2013). Interviewees were full of praise for the community design which facilitated quick, real time communication and agreed that such design as well as the embedded Latex writing system increased their willingness of participation. This is consistent with what has been suggested by CEM—giving users tools to improve their communication and socialization experiences or reduce the effort they devote to content development thus increase their participation motivations.

5.1.3. Rules

Research question 1.3 investigates the rules regulating activities on Economics Stack Exchange and Mathematics Stack Exchange. This study identified a set of explicit (set by Stack Exchange system) and implicit rules (set by individual Q&A sites) regulating the activities of scope development and community moderation. The creation of those rules on both Economics Stack Exchange and Mathematics Stack Exchange was based on the same collective pattern as that for the Q&A resource but was facilitated by the meta sites (same as the talk page of Wikipedia), and new users could review the discussion logs on meta site to get a fuller understanding why certain rule was implemented. Although the policy development process was governed by a mix of democratic and meritocratic mechanisms—the Stack Exchange community team and administrators of individual sites have more power to control and guide the policy design—the regulations such as the interpretation of rules, arbitration, and the identification of violation were more distributed among ordinary users based on the privileges they earned. Compared to Wikipedia and open source software development projects (Bonaccorsi & Rossi, 2003; Forte &
of informal mechanisms contributed to the development of rules, such as informal leadership, shared rules, informal mentoring, and communication protocols.

5.1.3.1. **Scope Development**

All Q&A communities on Stack Exchange could set their own rules of defining scope and handling out-of-scope and homework questions. Both content analysis of meta discussion threads and interview data analysis revealed that the Economics Stack Exchange and the Mathematics Stack Exchange had different scope settings as well as strategies to handle questions that were out of defined scope. In the private beta phase the founders of the Economics site chose a narrow scope for the site limiting it to advanced, graduate level questions, while when the site entered public beta phase, there was ongoing debates regarding the possible change of the scope—if more general, basic level questions should be allowed to increase traffics. Economics Stack Exchange never openly confirmed if the site scope has been changed. However, in practice the site still applied very strict rules to handle out-of-scope questions or homework questions. Such inconsistency and vacillation about scope setting made the site fail to attract potential ordinary users but also lost elite users who joined the site from the beginning. Mathematics Stack Exchange instead had a mix-topic scope during all phases and allowed basic level and homework questions, as long as askers provided enough background information and explained his/her thoughts on the problem. In practice, Mathematics Stack Exchange encouraged users to first check site scope before they posted questions and had a slightly boarder scope than what has been listed on meta site. If a question was voted/flagged to close or closed directly because it is a homework question or an out-of-scope question, comments should be left to explain why this question should be closed. Resnick, Konstan, Chen, and Kraut (2012) proposed that when
starting a new online community, a mixed-topic scope for one interaction space could reduce the expected value of a community. Findings of this study didn’t not support such claims. The scope of Mathematics Stack Exchange was not deliberately mixed, but a mixed-topic scope made each user sub-community (researcher, educator, student) to be able to use the site differently, and the ambiguity of scope for the community created more communication opportunities between different user sub-communities. The negotiations regarding community scope on meta site made each sub-community to understand other sub-communities’ demands thus had more tolerance to those contents they may not prefer. For example, users who identified themselves as researchers in general didn’t like homework questions, but they could at least learn why educators and students emphasized the teaching and learning aspects of Mathematics Stack Exchange. Also the activity of negotiating the scope could become a rewarding activity for some members, and lead them to feel ownership of the community, and thus commitment to it. However, such scope negotiation didn't not change users’ expected values of a community as suggested by (Resnick et al., 2012). Interviewees of Mathematics Stack Exchange explained although they appreciated the communication opportunities, they preferred not to interact with contents that didn’t meet their expectations of the community. That’s also the reason why interviewees of Mathematics Stack Exchange emphasized the usage of Stack Exchange embedded tag system and self-developed question filters, by which the search costs were reduced and each sub-community could just focus on questions they were interested in. Although Mathematics Stack Exchange was a global-defined community, looking the same to all members, these tools divided community members and content into multiple sub-spaces, thus both expert users and ordinary user traffic could be retained. This is consistent with Resnick et al. (2012)’ community design claim that in
communities with lots of interaction spaces, recommender systems that help people navigate to spaces that best suit them will increase the net benefits people experience.

A number of studies have highlighted the importance to peer production success of an appropriate and achievable scope, and well-defined and clear community goals or objectives. Empirical findings suggest that less than successful production outcomes can arise from excessively large scope, underestimating the scope of a project, changing scope or objectives, unclear goals or objectives, lack of agreement on goals or objectives among interested parties, or elusive goals that emerge and change as the project proceeds. According to Aladwani (2002), clear, well-defined project goals enable a community to develop a common understanding of the problem and so develop a unified (and therefore less risky) approach to solving it. Yetton, Martin, Sharma, and Johnston (2000) pointed out that success is more likely when project goals are well communicated to all concerned with the project. Lyytinen and Hirschheim (1988) suggested part of the cause of systems development failure lies in the fact that goals are often ambiguous, particularly with respect to technical, data, user or organizational requirements. The uncritical adoption of tangential goals and narrow perspectives can lead to expectation failure, particularly on the part of users. Findings of this study confirmed most of the claims above, suggesting either broad or narrow scopes can work for a Q&A community but the community scope setting needs to be consistent and better not to have ambiguity, and explicit statement and documentation must be provided if scope change is a must. The Stack Exchange management team should work with moderators on scope setting and changing and make documentation of changing process mandatory.
5.1.3.2. Community Moderation

Besides policies regarding scope management, most rules were related to community moderation. The Economics Stack Exchange and Mathematics Stack Exchange both used the reputation-based privilege system to control what users can do on the site. For example, users with enough reputation points can vote to close, delete posts immediately, or view deleted posts. Such design breaks large, complex moderation tasks into small, independent modules thus could provide members with a wealth of tasks that they are interested in thus reduce moderation workload of official moderators and provide an open structure thus supports coordination. Some other explicit rules identified by interview data analysis include discussing and searching on meta site and flagging and flag review. Users were encouraged to discuss policies, report bugs, or request features on meta site. They were also expected to first search to see if their questions have been asked before and do some research about how the meta site works before they post. They were instructed to create flags to bring inappropriate content to the attention of the community rather than handling it by themselves when they didn’t earn enough reputations. Once they have higher level privileges (e.g. close question privilege) they can act directly.

The Mathematics Stack Exchange developed more detailed informal practices to complement the explicit rules. Moderators of Mathematics Stack Exchange agreed they usually would not interfere when users have small conflicts in collaborative editing or flagging and flag review, only if users edit or flag/rollback the same thing within relatively short period of time, for example more than four times within a week or less. They also set up a separated tag review rule on Mathematics Stack Exchange. Users were allowed to add tags, but newly-added tags needed to be reviewed by a certain number of users, including moderators, to be functional. Unlike the explicit rules, the creation of implicit rules was based on the community members and did not
involve the Stack Exchange management team, thus violations of the implicit rules cannot be-punished through blocking and banning. However, interviewees of Mathematics Stack Exchange considered the site benefited from the creation and implementation of those implicit rules because they can remain fluid and be adjusted to emerging requirements.

Compared to Economics Stack Exchange, the Mathematics Stack Exchange emphasized user participations in community moderations at different levels. User participation in moderation is believed to play a role in shaping users’ perceptions of the social-technical system in a number of ways. By participating in moderation tasks, users can gain an understanding of the system being developed, which may influence their expectations about how the community will serve their interests. This may ultimately avoid a mismatch between user expectations and the community outcomes. User participation is also believed to improve users’ attitudes to, and involvement with the community. In other words, it is important that participation is meaningful, involving significant consultation, communication, personal autonomy, decision-making, responsibility and control (Gallivan & Keil, 2003; Lynch & Gregor, 2004; Wilson & Howcroft, 2002).

Another important aspect of user participation in moderation work was that it provided a forum for interaction and communication between different user groups. Such interaction is perceived to enable users to articulate their interests, objectives, and needs; to facilitate the mutual exchange of views and expectations, improving understanding; and to assist in constructive conflict resolution (Markus & Mao, 2004).

5.1.4. Division of Labor

Research question 1.4 examines the division of labor within activities on Economics Stack Exchange and Mathematics Stack Exchange. Division of Labor in Activity Theory refers to both the horizontal division of tasks between members of the community and the vertical division of
power and status. Those two sites did not present difference regarding the vertical division of power/status because Stack Exchange network defined it—there were four groups on Stack Exchange based on the account status, including Stack Exchange management team, moderators, registered users, and visitors. Except the visitor group, other three roles have been identified in both content analysis and interviews. Both the Mathematics Stack Exchange and the Economics Stack Exchange followed heavy tailed distributions--the majority of community members were not very active, and a small minority took on most responsibilities and privileges. Among this small minority, most of them were only registered users who did not have privileges associated with account status. Compared to other mature peer production communities such as Wikipedia that includes more than 20 different structural roles (Arazy, Nov, & Ortega, 2014), Stack Exchange made structural roles more implicit: community members could perform various content editing and moderation activities based on reputation points—even activities mainly performed by moderators—but their account status would still be registered users.

Regarding the horizontal division of labor, both content analysis and interview identified two unique groups on Mathematics Stack Exchange: quality manager and grassroots level manager. Quality managers were those who mainly preformed quality assurance tasks and some moderation tasks, including closing duplicate questions and other off-topic, opinion-based, low quality posts, reopening closed questions, flagging spams and abusive posts, locking posts, requesting features on meta site, performing site status analysis, and communicating with Stack Exchange management team. Grassroots level managers were those who mainly preformed content copy-editing and cleaning up work, including making comments to questions or answers, editing questions or answers, assigning or removing tags, migrating questions, or reporting bugs to the Stack Exchange management team on meta site. In additional to content expert like
content creators and reviewers, a successful peer production community also needs members to perform routine but important quality assurance and other community supporting work (e.g. copy-editing, meta-content work). Previous studies also featured similar user roles (e.g. content justifiers, copy editors, cleaners, steward, etc.), but many of these roles reflected users’ access or activity privileges (Arazy et al., 2014; Forte, Larco, & Bruckman, 2009; Niederer & Van Dijck, 2010), and emphasized upward transitions towards leadership positions (e.g. from user to content creator, from content creator to administrator, etc.) (Preece & Shneiderman, 2009). The horizontal division of labor identified in this study instead reflect more on users’ preference of certain tasks, either due to their personal interests or commitment to the community, because most users did have enough reputation to perform more advanced-level, administrative tasks (see section 4.3.4.2). The social roles on Stack Exchange are not divided based on successive levels of involvement and progression, but different ways in which users want to participate in online communities and the various activities they are willing to take part in. Although administrators used to take other roles such as content creators, grassroots level managers, reviewers, or quality managers, those roles must not be seen as a step towards becoming an administrator/moderator; instead, they represent functional positions that are important in their own right. The decentralized, distributed governance model on Stack Exchange may affect the formulation of social roles, because most administration activities are not restricted to formal administrator positions (moderators), and these activities are distributed between many other community members (e.g. reviewers, quality managers, etc.).

The roles and responsibilities of in a peer production community need to be well-defined and clearly communicated to community members. Empirical studies have found that lack of clarity of role definition is significantly negatively related to community success (Jiang & Klein, 1999,
When roles and responsibilities are poorly defined or communicated, requirements may be overlooked, items or features may be left out or not completed, or there may be significant task overlap (Keil et al., 2002). The Stack Exchange network should consider to customize reward policies and reputation systems on individual Q&A sites to encourage activities within and clear definitions of certain user roles.

5.1.5. Tools

Research question 1.5 examines the tools used and in activities on Economics Stack Exchange and Mathematics Stack Exchange. Table 4.3.6 lists the tools identified from semi-structure interviews, including tools of question answering, content editing, searching and browsing, computation, graphic design, program, communication, moderation, and user education. Content analysis also identified meta discussions regarding management tool and editing tool development (table 4.4). Although users of Economics Stack Exchange and Mathematics Stack Exchange both discussed tools needed for content editing and community moderation, only users of Mathematics put the tool development ideas into practice based on the findings of interviews. The CEM suggests that community members’ motivations to contribute to a community task will be increased (thus social loafing in a community can be reduced) if tools are given to (a) reduce their efforts to perform a task, (b) help them achieve better performance for a given effort, (c) enhance the relationship between their individual performance and the community performance, (d) help their collective performance be evaluated by others, (e) split work into smaller rather than large groups, (f) make their contributions to the collective product are unique, rather than redundant with the inputs of other group members, (g) compare their performances with a standard, (h) help them to find tasks that are intrinsically interesting, meaningful to them. Tools identified in this study fit the above categories. Content editing tools such as embed Latex
renderer and Lyx reduced user efforts of adding mathematical formula; question-answering resources such as Wikipedia and textbooks helped users better answer questions; the voting mechanism help to evaluate user performance; the privilege system distributed review tasks to different review queues; the Help center and policy discussion pages on meta site provided official guidelines and standards to evaluate users’ performance on question-answering and community support tasks; the embedded tag system and self-developed filters helped users find questions and community support tasks they felt interesting and meaningful.

There are clearly many considerations relating to tools (e.g. software, technology, etc.) that can potentially influence the outcome of a peer production such as Wikipedia and open source software projects. For example, the use of appropriate technology is perceived to be important for project success in some cases (Somers & Nelson, 2001; Wixom & Watson, 2000), but not necessarily in others (Fortune & White, 2006; Oz & Sosik, 2000). In this study, different tools were selected for specific activities depending on their objective, community, and subject. Some of the tools were only developed and used by members of Mathematics Stack Exchange. The moderators mainly used the internal tools provided by Stack Exchange (moderation tools based on privilege system) and some self-developed external tools (trackers of unanswered questions, pending reviews, low-quality posts, recently active questions, etc.) to preform moderation tasks. Some communication tools, such as Help center, meta site, private chat rooms, were used by moderators to communicate moderation issues. The moderator wrote user tutorials for education purpose. The quality assurance managers used moderation tools based on privilege system to perform quality assurance tasks such as upvoting, downvoting, or locking posts, flagging spams and abusive posts, closing duplicate questions and low-quality posts. They also used communication tools such as the meta site to request features, communicate with Stack
Exchange management team, or post analysis result of community status. The Reviewers used the review system to review tags, suggested edits, and various types of posts in different review queues. The grassroots level managers mainly used content editing tools such as stack Exchange editor, embedded Latex renderer, and other self-developed tools to edit questions and answers, make comments to questions and answers. They also used searching and browsing tools to assign and remove tags and migrate question. The meta site were used as a communication tool for them to report bugs. The content creators mainly used question and answers on other Stack Exchange sites and some other question-answering tools such as text books and notes, Wikipedia, other online math knowledge repositories, and content editing tools to answer questions. They also used computation, graphic design, and programming tools to help write answers. Searching and browsing tools including embedded tag system and other self-developed question filters were used by them to select questions they felt interesting and meet their expectations of the community goals. Ordinary users also used the searching and browsing tools to choose questions they were interested in or meet their learning objectives. Occasionally they used the meta site as a channel to learn community policies and other community decision.

Findings of this study confirmed that adequacy of developing tools was significantly positively associated with project performance (Aladwani, 2002). Stack Exchange network should either add cross-community tools/features to support content editing, searching, communication, moderation, and user education, or use reward/reputation system to encourage tool-feature development by members of individual sites.

5.1.6. Contradictions

Activity theory uses the term contradiction to indicate a misfit within elements, between them, between different activities, or between different developmental phases of a single activity
Contradictions manifest themselves as problems, ruptures, breakdowns, clashes, and had important implications for tools, practices, and division of labor (Collins, Shukla, & Redmiles, 2002; Kuutti, 1996). Identifying the contradictions that exist in and between activity components and seeking resolving those contradictions can lead to the evolution of and innovation in the activity system (Engeström, 1987). The following sections provide different a summary of contradictions that occur within or between components of an activity system and some solutions for resolving those contradictions are suggested.

5.1.6.1. **Contradictions Within a Single Component**

There is a primary contradiction of the perceived object of their activities of between the researcher subject group and educator/student subject group, who have different opinions regarding the community goal and scope, as well as how to deal with homework questions. This is an inner contradiction existing within a single component (object) — the objective of subject group appears to be in conflict — the researcher group preferred a restricted scope and did not allow homework questions, while the educator/student group considered homework questions should be welcomed to facilitate learning. As discussed in section 5.1.5.2, primary contradiction is not necessarily negative to community success. Acknowledgement of contradiction can ensure new or creative solutions are considered, arguably leading to better decision making, if it encourages meaningful and constructive debate among participants (Sawyer, 2001).

Economics Stack Exchange and Mathematics Stack Exchange used different strategies to handle such a conflict. Members of Economics Stack Exchange insisted that the site should remain as a researcher community and developed a policy of only allowing graduate-level economics questions that emphasizing the research aspect, thus the educator/student communities shrank and eventually vanished. Both sub-communities on the Mathematics Stack Exchange instead
reached an agreement that homework questions would be allowed if askers explained his/her thoughts on the problem, and actively educated members to use tags to browse only questions they have interest to answer. This is a compromise between different subject groups in order to reconcile their difference, in the face of the realization that no one side will be completely satisfied. Tags were used to create separated subspaces for sub-communities with different perceptions of the community purpose and scope, although that’s not the design intention of the embedded tag system. Creating several subspaces in one community could reduce search costs for members: one can only follow those question categories they are likely to be interested in and avoid to see questions they don’t like. To resolve similar contradiction on other Q&A sites, Stack Exchange network could add question filtering features to it embedded tag system, thus users can use the filters to avoid certain categories of questions directly.

5.1.6.2. Contradictions Between Object and Tool

The contradictions between object and tool are secondary contradictions--the cases where *inabilities of a tool prevent the object of an activity from being met*. Interview data analysis identified nine contradictions between object and tool (see Table 4.13). Since Economics Stack Exchange and Mathematics Stack Exchange were hosted on the same platform, those contradictions existed on both sites, but five of them were reported only by users of Mathematics Stack Exchange. Some contradictions occurred simply because there were no tools to meet certain objectives, including identifying duplicated questions, filtering questions, rediscovering questions, migrating questions, performing user analysis, and messaging between members. Those contradictions were likely to be resolved by members themselves. Interviewees of Mathematics Stack Exchange mentioned, in order to resolve those contradictions, they have self-developed content searching, browsing, filtering, and moderation tools, and posted tutorials on
meta site to teach other users how to use those tools. The Stack Exchange community team actually asked for cession (grant certain privileges or badges to exchange) about some tools developed by users, such as the automatic low-quality post detector developed by members of Mathematics Stack Exchange. Another three contradictions occurred between the existing tools and the objectives they are supposed to serve, such as writing and searching posts in Latex, or attracting new users. The embedded Latex renderer could cause a lot of slowdown and was unable to scroll the output if users were writing long answers, and the search system had problems in dealing with Latex strings, making search for math formulas impossible. The front-page of each Stack Exchange Q&A site only allows very few questions staying on it, thus it is highly likely new users are unable to identify any interesting question when they first come to the site. Those contradictions can only be resolved by the Stack Exchange management team who is able to implement tool/system changes across different Stack Exchange Q&A sites.

5.1.6.3. Contradictions Between Object and Rule

The contradictions between object and rules refer to cases where specific rules create barriers that inhibit the subject from meeting his/her objective. Interview data analysis identified seven contradictions between object and rule. Similar to the contradictions between object and tools, four were only reported by interviewees of Mathematics Stack Exchange (see Table 4.13). Those contradictions can be loosely categorized into three groups: no rule, a misled rule, or a rule cannot be enforced, regarding a certain objective. For the objectives of preventing personal attacks, resolving conflicts between moderators, preventing question close-open war, contradictions occurred because there were no official rules and moderators have to deal with those issues on a case-by-case basis. Two contradictions occurred when existing rules were gambled or misled thus cannot meet the original objectives. The reputation-based privilege
system was designed to facilitate high quality content creation. However, since reputation points have no relation with question difficulty, users could game the system by answering lots of easy questions that do not have much value. The Stack Exchange community team realized the reputation hunting contradiction, and introduced bounty to encourage answers to difficult, research oriented questions. However, compared to the effort devoted, the value of bounty is still much lower than answering many easy questions thus cannot effectively prevent reputation hunting. A possible solution is to associate rewards with the difficulty of questions or other activities with estimation of the efforts users need devote to perform these activities. For the objectives of user education and facilitating user communication during question closing process, users came to some informal rules that general practice could follow, but those rules were highly instructive and difficult to enforce thus failed to meet those objectives sometimes. Users were encouraged to check the meta site and other tutorials before posting questions, but there was no way to enforce such practice. Thus many users concentrated on asking for help and/or providing answers, and largely ignored the discussions about site policy and maintenance, even if for those issues they cared about. Similarly, users were encouraged to leave comments to explain why they thought a certain question should be closed when they casted a close vote or closed it directly, but that was also instructive. Moderators did discuss with the Stack Exchange community team if those rules should be turned into compulsory, and eventually withdrew after considering the entry barriers may cause tensions between managing quality/facilitating communication and encouraging contribution. Subjecting users to a more arduous initiation process could indeed cause them to forego participating in the community (Drenner, Sen, & Terveen, 2008). Comparing to the first two types of contradictions, those contradictions were kept by moderators as a trade-off between policy design and maintaining a large number of user base.
5.1.6.4. *Contradiction Between Object and Division of Labor*

The contradictions between object and division of labor refer to cases where the division of tasks among members inhibits the objective of an activity from being met. One contradiction shared by the Economics Stack Exchange and Mathematics Stack Exchange was lack of content creators with enough domain specific knowledge to minimize the number of unanswered questions, but the reason the causing this contradiction was quite different. Contradictions of moderator qualification and content quality manager were reported only by members of Mathematics Stack Exchange, simply because the Economics Stack Exchange didn’t have moderator election and content quality managers. Contradiction regarding moderator qualification refers to the contradiction between the capability of moderators—the division of labor—and the objective of moderating the site successfully. When casting moderator vote, users tended to evaluate candidates based on their reputations rather than moderation experience, thus elected moderators may not have the capability of moderation. Contradiction regarding quality manager refers to the contradiction between the working practice of quality manager and the objective of encouraging posting questions. Some quality managers on Mathematics Stack Exchange tended to close questions very quickly, making the site less well-coming than it used to be and harsh to new users.

The contradictions between object and division of labor reported in the current study is similar to the top management issue in management research. In the management literature, top management refers to the group of most senior executives and decision makers with responsibility for the overall strategic direction of the organization. Lack of top management support is considered an important project risk factor in information system research. Failure of top management to monitor progress, support and enforce management and control procedures,
or be involved in critical decisions can cause project failure or abandonment (Oz & Sosik, 2000). Top management support is also considered important in shaping the context of a system, influencing how users appropriate a system, including user attitudes and commitment to a system (Sharma & Yetton, 2003). The Stack Exchange network should consider to formalize moderator election standard and process, and give more reputation points to those experts who are willing to answer unanswered questions or develop more effective question discovery tools.

5.1.7. Skills

Research question 1.7 focuses on skills required to participate in Economics Stack Exchange and Mathematics Stack Exchange. This study identified a list of eight skills that were perceived important by the interviewees, including basic domain-specific knowledge, understanding the question correctly, written communication, good control of English, writing in Latex system, interpersonal and social skills, teaching skills, and adaptability. The teaching skills was only mentioned by interviewees from Mathematics Stack Exchange, because the educator and student communities emphasized the treated the site as an online teaching and learning platforms. Most interviewees felt that written communication, good control of English, and being able to write in Latex system were the most important skills. This is not surprising since good interpersonal and communication skills are perceived to be important for interacting with users, and for facilitating dialogue between different groups of users in other types of peer production such as open source software projects. For example, Hornik, Chen, Klein, & Jiang (2003) found low levels of user satisfaction in system development projects where users perceived the developers to have poor communication skills, regardless of their technical expertise.

Some of the internet skills and digital literacy skills identified in previous studies were also mentioned in the this study. For example, Deursen and van Dijk (2010) proposed a framework
The information internet skills, which refers to one’s ability to define an information problem, select information, and evaluate information sources, correspond to skill of understanding the question correctly identified in this study, which refers to the ability to understand what’s being asked and interpret the question in a reasonable way. The interpersonal and social skills were mentioned in (Alkali & Amichai-Hamburger, 2004) as subcategories of social-emotional literacy, which refers to the abilities of understanding the rules of the community and surviving the hurdles that await users in the mass communication of the cyberspace. If community development is as much a social activity as a technical one, then adaptability and change-management skills may be necessary for participants (Symon, 1998). Interviewees pointed out that such soft skills were equally important as subject knowledge, but may be ignored especially by those users who have already established high reputation profiles in their own networks:

“New users face a learning curve independent from their level of mathematical sophistication. The site has developed its norms, do’s and do-not’s that are somewhat different from what they seem to have expected. So a new user needs to invest some time learning the ropes. Not all more senior mathematicians are flexible enough to get past this point. I recall having had a few surprises myself, but others have arguably had it worse. it also requires mental confidence and resilience. When you first join the site, you are likely to break some rules. This will attract downvotes, close votes, and these comments are not always kind. It can be very disheartening, and participating in the site successfully requires that you can handle this negative feedback and recover from it.”
5.2. Community Success Criteria and Metrics

The second research question examines the community success criteria and measures used by Stack Exchange network, whether and how they influence community dynamics of those two Q&A communities, community success indicators/factors from users’ perspectives, and criteria of high-quality questions/answers.

5.2.1. Criteria and Metrics Set by Stack Exchange

Research question 5.1 examines criteria and metrics set by Stack Exchange network, and if they have influenced community dynamics. Content analysis of policy pages of Stack Exchange identified criteria and metrics used by Stack Exchange to evaluate community status and decide if a Q&A community should move to next phase (section 4.1.5). Most criteria addressed influential factors that considered to be related to community health in previous research, such as topic management (Aladwani, 2002; Somers & Nelson, 2001), amount of developing activities (Stewart, Ammeter, & Maruping, 2006; Subramaniam, Sen, & Nelson, 2009), user participation (Doherty, King, & Al-Mushayt, 2003; Wixom & Watson, 2000), and social interactions (Choi et al., 2010; Morgan et al., 2013; Procaccino, Verner, & Lorenzet, 2006).

Interview data analysis shown most participants were aware of and agreed that those criteria and metrics were in general reasonable and effective to reflect the potential of a Q&A community. Some interviewees of the Economics site have complaints about the site closing process and doubted if the Economics site was closed due to its performance, since the criteria used by Stack Exchange to evaluate public beta sites were very vague. They argued Stack Exchange should make graduating metrics in public phase more explicit rather than just publish hard limits that do not guarantee a site to be launched once met.
Content analysis of site management discussion threads found that members of both sites used some strategies to meet those criteria set by Stack Exchange to help the site move to the next phase. Interviewees of both sites confirmed the usage of those strategies. The community development strategies used in Economics site include: (1) set different site scopes in private beta and public beta phases; (2) avoid unknowable or highly opinionated questions; (3) post “pseudo” questions which users normally not consult others for; (4) answer all unanswered questions even if those questions did not fall into the intended scope; (5) recruit high-reputation users from other Stack Exchange Q&A sites. The Mathematics site instead mainly focused on recruiting high-reputation users. Community developing strategies, especially those created inconsistency in scope setting or unusual traffics didn’t seem to help with the community growth. This may also be the reason why Stack Exchange didn’t set explicit metrics (e.g. question answer ratio, visits per day, etc.) for beta phases to prevent users gaming the evaluation system. However, it is worthwhile to establish standard practice for site closing process that can benefit members of a failed site if they plan to rebuild it.

5.2.2. Community Success Indicator/Factor

Research question 5.2 examines indicators of a successful social Q&A community from users’ perspective (see section 4.3.10). Most indicators of community success proposed by users confirmed findings in previous studies, such as community size, high user participation level, member turnover, and social interactions between users (Bateman, Gray, & Butler, 2011; Blanchard & Markus, 2004; Qi, Salter-Townshend, & Cunningham, 2014; Ransbotham & Gerald, 2011; Ren et al., 2012). Social network analysis suggested a Q&A community whose user network was connected by high profile users and facilitated discussion among its members was likely to succeed.
Online communities provide limited value if their size is very small because members derive benefit from contributions made by other members. Large size can signal to both members and non-members that a community is active and vibrant, and can implicitly affirm its value (Bateman et al., 2011; Ren et al., 2012). Prior research also suggested that developing a membership base that is willing to remain engaged is key to community success, and member withdrawal has significant negative effect on social capital and thus community outcomes (Butler, Bateman, Gray, & Diamant, 2014; Qi et al., 2014; Ren et al., 2012). Compared to previous research, findings of this study emphasized the diversity of membership—contributions from a mixture of users with different objectives or expertise levels (both new and experienced) could increase the likelihood of community success. Moderators of individual Q&A sites or the Stack Exchange management team might seek intentionally cultivate a core group of members who participate over the long term, such as by offering privileges to a small number of members who agree to remain active in the community. However, they also should encourage the community to remain open to outsiders, who can join and leave at will. Such outsiders do not necessarily need to remain active in the community; rather, the long-term members and moderators should find ways to organize and preserve their contributions, even if they leave. It also may be necessary for members of the core group to leave eventually, which allows new members to assume leadership roles and introduce new resources to meet the changing collaborative needs of the community.

5.2.3. Criteria/Metrics of High-quality Questions and Answers

Research question 5.3 examines criteria and measurements/metrics that were perceived as effective to select high-quality questions and answers. The interview data suggest a set of quality criteria that were considered important by the interviewees (see Table 4.16). Most quality criteria
can be mapped to those in previous studies (Chai, Potdar, & Dillon, 2009; Emamjome, Rabaa’i, Gable, & Bandara, 2013; Ge, Helfert, & Jannach, 2011; Kim, 2010; Kim & Oh, 2009; Shah & Pomerantz, 2010; Zhu, Bernhard, & Gurevych, 2009), except show effort (for question), inspiring (for question), educational (for answer), and enlightening (for answer). All these four criteria were proposed by interviewees from the Mathematics site partly due to the existence of the educator/student groups, and were expected to influence user’s voting behaviors. Although the Mathematics site allowed homework questions, it required askers to provide enough context information, share their own thoughts, and show some efforts in their questions so the Mathematics site would not appear to be a homework solving site. Such requirement was set to increase the participating motivation of the educator group, since those users who were willing to answer homework questions used it as a text to see if a question is worth to answer or not. The criterion of show effort was also set to comfort the researcher group, the group definitely disliked routine textbook exercises—from the researcher group’s view, if it’s not a mathematics interesting question, it’s much better if the motivation is clear and what are some of thoughts askers have. Accordingly, Educational was a criterion emphasized by the educator group for high-quality answers. While a high-quality question should indicate an appropriate amount of effort, from an educator’s perspective, a high-quality answer should communicate the ideas rather than to show all of the work that needs to be done by the asker. Ideally, it should provide further detail or further reading or external links for those who may be interested in learning more. Inspirational/Enlightening are similar criteria that emphasized the research value of questions/answers—from the researcher group’s perspective, a high-quality question/answer should be mathematics interesting and in the sense of paying some thoughts. According to CEM, individual’s motivations contribute to a task is positively correlated to an individual’s perceived
value of the outcome of the task. Thus if a question presented more mathematics value, users were more willing to answer it.

Findings of this study confirmed that different patterns exist between subjects and high-quality question/answer selection criteria identified by users (Harper, Raban, Rafaeli, & Konstan, 2008; Kim & Oh, 2009). Unlike previous studies, this study suggested participating objectives could affect users’ perceptions of high-quality questions/answers. Currently the study site, Stack Exchange network, uses the same site design for every Q&A site it hosts. Based on the subject area that a certain Q&A site addresses, policy designers could customize a unique reward system to give more points to those questions/answers that present features of high-quality content which users of that Q&A site would appreciate. Design of merit badges could also emphasize the features of high-quality answers each Q&A site has and the preferred selection criteria identified by its users.

5.3. Limitations

As with any study, the findings from this dissertation face some limitations. First, community success in this study was defined as community longevity. This is how the Stack Exchange network defines community success, thus may not reflect community nature and user need of community members of other forms of online peer production communities or even other social Q&A systems. The majority of current literature studying definitions of success in online peer production communities focused on open source software. Many of those projects have no clear endpoint and place more focus on project delivery rather than longevity of the open source software communities. Thus findings from this study may not be generalizable to other types of online peer production communities. Second, due to the absence of a good sampling frame and the small size of the sample used in the interviews, the study may not have captured the full
range of user practices and experiences with those two Q&A communities. For example, not all users in different user sub-groups were guaranteed to participated in interviews—there were much fewer users who identified themselves as educator/students were willing to share their user profiles and contact information, thus the interview data was dominated by the researcher group. In general, it was impossible to rely on voluntary user profile information to select a well stratified representative sample. Third, using a case study approach without more quantitative evidence (e.g. results from surveys or experiments) placed limits on the generalizability of the study’s findings. One cannot conclude from this study that a particular community building activity or strategy is better than another one. Follow-up research with more quantitative data is necessary, as discussed in section 5.4.

5.4. Conclusion and Future Research

This study applied Activity theory to examine the community building activities and strategies, as well as user interaction patterns of two Q&A communities on Stack Exchange network. The concepts and principles of Activity Theory helped formulate research questions, develop research design, and analyze activity logs and interview data. Collective Effort Model was used to analyze community structure, sociability-support, and technological components regarding the motivating contributions, control content quality, and other community supporting works. This study took a case study approach, where a detailed and intensive analysis of individual case—the Economics Stack Exchange and the Mathematics Stack Exchange—was performed. A mixed methods design was utilized, combing content analysis, social network analysis, and semi-structured interviews. The content analysis of activity logs enabled researchers to identify community building strategies and user profiles of each Q&A community, learn about criteria the Stack Exchange network used to identify community success and how those criteria shaped
community dynamics, and develop an initial list of categories of community building activities and division of labors, and prepare for social network analysis. The social network analysis helped the researcher learn user interaction patterns and features of community network on each Q&A community, and identify a list of potential interviewees. The semi-structured interviews with users of each Q&A community allowed researcher to validate and extend the findings attained from content analysis, gain deeper understanding of the findings, identify participating motivations, communities, tools, rules, contradictions, skills, and know about the criteria and metrics that users considered as indicators of community success and high-quality questions/answers. The research design and theories used in this study can be applied to other similar studies examining the community dynamics of sociotechnical systems.

All the research questions formulated in the study were addressed, and a synthetic view of the findings gained from the three research methods was presented in this chapter. The findings indicated that compared to the Economics Stack Exchange, the Mathematics Stack Exchange Q&A community devoted more efforts to activities of quality assurance, user management, tool development, promotion, and communication between members. It also set clear rules regarding community scope management and user moderation, as well as documented instructions to implement those rules. Besides content creators and moderators, the Mathematics Stack Exchange had unique user groups who were responsible for quality control, meta-content, and other community supporting work. The Mathematics Stack Exchange community also engaged in developing tools of question answering, content editing, searching and browsing, computation, graphic design, program, communication, moderation, and user education. Comparing to that of the Economics Stack Exchange, user network of the Mathematics Stack
Exchange was connected and expanded largely by high-profile users such as moderators and high-reputation content contributors.

Findings in this study are expected to advance the theoretical understanding of the underlying mechanisms of successful peer production systems (especially theoretical claims of early stage community ecology and developing strategies), for example in mixed scope setting, user selection and recruitment, motivating contributions, etc. (Resnick et al., 2012). This study could also provide practical guidelines to designers of existing peer production communities as well as individuals, groups, and organizations who intend to start, maintain, and/or grow a new community. For example, policy system designers on Stack Exchange should add policies to prevent personal attacks, resolve conflicts between moderators, minimize question close-open war; emphasize user education on meta and conversations during content review process; Revise reward policies/reputation system (in general) to prevent reputation hunting; customize reward policies/reputation system on individual sites to encourage good informal practices, certain user roles, and healthy user interaction patterns. System designers should add cross-community tools/features to support content editing, searching, communication, moderation, and user education; or use reward/reputation system to encourage tool/feature development by members of individual sites.

Future research includes a survey to generalize findings regrading community building activities and strategies of other Q&A communities, and community success criteria and measures users perceived as effective for a Q&A community’s performance. Findings of the current study could be compared to other social Q&A sites in the same subject areas but hosted by different platforms or systems. A peer production community’s success may be affected by its relationship with other similar communities--such as how the topics it covers and members it attracts relate to
those of other communities. The online ecological structure complicates understanding of the success of peer production communities—all online communities exist within a larger population of communities, with which they compete and cooperate. For example, when programmers participate in many programming-related Q&A sites simultaneously, the competition for shared members’ time and effort could reduce the resilience of these online communities. The knowledge, experience, technical, and management skills that programmers obtain from one Q&A site might transfer to, and thus support, other communities. Empirical studies may provide new perspectives on the underlying principles of peer production success, as well as offer important practical insights to better manage peer production. Another future research direction is to examine the factors that determine how practices are internally transferred and effectively adapted among peer production communities. Online communities often need to transfer best practices internally from one unit to another to improve their performance. For example, many non-English language Wikipedia versions have borrowed policies and procedures originally developed in the English Wikipedia. While the efficacy of particular practices has been studied in isolation, very few studies have addressed if such transfer could achieve the same level of effectiveness of the original model, as well as how acquiring and changing these practices may influence their effectiveness. The current study can be extended by analyzing the effects of same set of practices in different Q&A sites on the Stack Exchange system and cross-linking key participants’ activities in those sites during the given time period.
APPENDIX A

CODE OF MATHEMATICS/ECONOMICS STACK EXCHANGE META DISCUSSION

1. **Site scope development**: Define scope, Clarify/Enforce scope, Site goal discussions, Specific question handing, Closed question discussions/disputes, Scope overlaps (with other sites) discussions

2. **Community governance**: Site policy discussions, Site policy clarifications, Explanations/Ask for explanation, Moderation discussions/expectations, Conflict mediation/consensus-seeking, Vandal/spam fighting, Site status reporting/evaluations, Site promotion, Call for participation/contribution/vote, Other governance issues

3. **Community development strategies**

4. **Membership and role management**: Target user group analysis, User recruiting, Expert recruiting, User behavior regulations, User Education, Moderator election/feedback/complaints

5. **Community supporting system**: Reputation system, Privilege system, Reward/Bounty system, Voting system

6. **Content development**: Content format requirements, Reference/source requirements, Management tool development (FAQ, templates, example question list, community wiki), Editing tool development, Duplicated content management

7. **How ask questions**: Question asking strategies, Question editing/rephrasing

8. **How answer questions**: Question answering strategies, Answer editing

9. **Quality control**: Question concern/evaluation, Quality control action

10. **Feature request/suggestion**

11. **Meta-content work**: Metadata/controlled vocabulary development, Classification, Archiving

12. **Benchmarking with other communities**: Experiences from other sites, Site comparisons, Propose other similar sites

13. **Site design**: FrontPage/dashboard design, General interface design, Domain name suggestions, Site name suggestions, System/script error reporting

14. **Site closing process**: Migrate questions, Future plans/What is next, Other feedback/Reflections
APPENDIX B

INVITATION LETTERS AND INFORMATION CONSENT

Interviews

Interview Invitation Letter

Subject: Follow-up interview on [Math Stack Exchange / Economics Stack Exchange]
community dynamics and developing strategies

Hi, my name is Hengyi Fu, and I am a doctoral candidate at the Florida State University
School of Information. I’d like to invite you to participate in an interview to discuss your use of
[Math Stack Exchange / Economics Stack Exchange] as an individual, your interactions with
others in groups and communities, your reflections of the community’s functions and design.
The purpose of this study is to understand the difference in successful and unsuccessful online
peer production communities and identify success factors in each stage of community evolution.
Your responses to interview questions will help me to understand how your community defines
community purpose and scope; how it recruits, selects, and keeps community members; how it
motivates members’ contribution, decides the community structures, and maintains the quality of
community outputs. The study is being conducted independently of [Math Stack Exchange /
Economics Stack Exchange].

If you agree to take part, I will interview you and ask you about your experience of [Math Stack
Exchange / Economics Stack Exchange] as an individual, your interactions with others in groups
and communities, your reflection of the community function and community design. The
interview would take about an hour, using your choice of online audiovisual media (Skype,
Google Plus Hangouts, or Apple FaceTime) or telephone. With your explicit permission, the
interview will be audio recorded using computer software. Being interviewed has minimal risks to you as a participant, believed to be no more than the risks you experience in everyday life. By participating you may benefit indirectly, as a user of a social Q&A community, from improved community design, usability, services, and an overall better understanding of the social elements and dynamics of social Q&A communities. For completing the interview, you will earn a $30 Amazon gift card.

Records of your interview and your identity will be kept private and confidential to the extent permitted by law. Research records will be stored securely and only I, Hengyi Fu, will have access to the records.

Would you be willing to be interviewed? If so, please reply to this e-mail with your preference of media, and we can work on setting up when the interview will take place. If you have any questions, please ask them in your reply. Thank you in advance for your participation!

Hengyi Fu

Doctoral Candidate, Florida State University

School of Information

College of Communication and Information

Interview Informed Consent Statement

FSU Behavioral Consent Form

“A Life-Cycle Perspective on Community Dynamics and Developing Strategies in Successful and Unsuccessful Online Peer Production Communities”
You are invited to be in a research study of [Math Stack Exchange / Economics Stack Exchange] community dynamics and developing strategies. You were selected as a possible participant because you visited or are a member of [Math Stack Exchange / Economics Stack Exchange] site. I ask you to read this form and ask any questions you may have before agreeing to be in this phase of the study.

This study is being conducted by Hengyi Fu, a doctoral candidate at the Florida State University School of Information, under the supervision of Dr. Besiki Stvilia, an associate professor at the School. The study is being conducted independently of [Math Stack Exchange / Economics Stack Exchange].

**Background Information:**

The purpose of this study is to understand the difference in successful and unsuccessful online peer production communities and identify success factors in each stage of community evolution. [Math Stack Exchange / Economics Stack Exchange] are examples of successful and unsuccessful social Q&A communities started on the same day. I am interested in your use of [Math Stack Exchange / Economics Stack Exchange] as an individual, your interactions with others in groups and communities, your reflection of the community function and community design. Your responses to interview questions will help me to understand how your community defines community purpose and scope; how it recruits, selects, and keeps community members; how it motivates members’ contribution, decides the community structures, and maintains the quality of community outputs.

**Procedures:**

If you agree to be in this study, you would participate in an interview with me where I would ask about your experience with and use of [Math Stack Exchange / Economics Stack Exchange] as
an individual and as part of groups and communities. The interview will take place using your choice of online audiovisual media or telephone. If you select the online option, the interview may take place using Skype, Google Plus Hangouts, or Apple FaceTime at your choosing. I estimate the interview will take about an hour to complete. With your explicit permission, the interview will be audio recorded using computer software.

**Risks and benefits of being in the Study:**

The study has minimal risks to you as a participant, believed to be no more than the risks you experience in everyday life. By participating you may benefit indirectly, as a user of a social Q&A site, from improved community design, usability, services, and an overall better understanding of the social elements and dynamics of social Q&A communities. You may directly benefit from reflecting on your experience with and use of [Math Stack Exchange / Economics Stack Exchange] as part of the interview.

**Confidentiality:**

The records of this study will be kept private and confidential to the extent permitted by law. In any sort of report I might publish, we will not include any information making it possible to identify you or other participants. Research records, including the audio recording, transcript, and interviewer’s notes will be stored securely and only the researcher, Hengyi Fu, will have access to the records. All research records will be deleted, or shredded five years after the completion of this interview or April 30th, 2019, whichever is sooner.

**Voluntary Nature of the Study:**

Participation in this study is voluntary. Your decision to participate or not will not affect your
current or future relations with Florida State University, [Math Stack Exchange / Economics Stack Exchange], or any other site, institution, or organization. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

**Contacts and Questions:**

The researcher conducting this study is Hengyi Fu, a doctoral candidate, under the supervision of Dr. Besiki Stvilia, an associate professor, of the Florida State University School of Information. You may ask any questions you have at the beginning of the interview. If you have a question later, you are encouraged to contact me via email or via phone, or Dr. Stvilia via email or via phone.

If you have any questions or concerns about this study and would like to talk to someone other than the researcher(s), you are encouraged to contact the FSU Institutional Review Board (IRB) at 2010 Levy Street, Research Building B, Suite 276, Tallahassee, FL 32306-2742, or (850) 644-8633, or by email at humansubjects@magnet.fsu.edu.

I encourage you to print a copy of this information to keep for your records, or you may always access it at [permanent URL].

**Statement of Consent:**

I have read the above information. I have asked questions and have received answers. By clicking the “Provide Consent” button below, I consent to participate in the study.
APPENDIX C

INTERVIEW QUESTIONS

Background Information
1. Can you tell me about your current position?
2. What is your highest degree? Where and when did you get your highest degree? What was the formal discipline of your degree?
3. What are your research interests?
4. Do you hold any other professional positions? If yes, can you tell me what are they?

Activities in Economics Stack Exchange/Mathematics Stack Exchange at Startup Stage
5. When did you start to participate in this community?
6. How did you get interested in this community and why did you participate?
7. Did you participate in other social Q&A sites (both inside and outside of the Stack Exchange system)?
8. How did you participate (e.g., post/comment on question and answers, edit answers, create/review tags, flag questions or answers, meta discussion, site management work, etc.)?
9. What are some of the sources that you used to answer questions except your all knowledge base?
10. What are some of the tools (e.g., editing tools, programming tools, communicating tools, answer templates, tag wikis, etc.) that help you participate in?
11. Are you aware of any formal or informal rules that moderating the community (e.g., how to solve conflict, how to prevent editing war, how to deal with questions that are out of the scope of the site, etc.)? If yes, can you tell me what are they?
12. What do you think, are there any formal or informal user roles in the community? If yes, that do you think, what role(s) do you play?
13. What skills (e.g., writing, programming, communication, etc.) do you think are needed to participate in except subject knowledge?
14. Did you encounter any problem or inconvenience when participating in Economics Stack Exchange/Mathematics Stack Exchange? How were those problems resolved?
15. Did you interact with other members outside of the system?

Success Criteria and Factors
16. Are you familiar with the criteria/measures/metrics used by the Stack Exchange system/platform to measure the progress of a Q&A community? If Yes, do you consider those criteria valid and effective? Why? Why not?
17. If Yes in question 18, What did you do, or observe the community did to meet those criteria set by Stack Exchange network?
18. What do you think, what could be some of criteria and/or measures one can use to assess how successful a Q&A community is?
19. What are some of the features (e.g., site design, policy, mechanisms etc.) you consider Mathematics Stack Exchange could add?
20. What are some of the criteria or characteristics of a high-quality question in your opinion? Can you give me an example?
21. What are some of the criteria of characteristics of a high-quality answer in your opinion? Can you give me an example?
APPENDIX D

APPROVAL FOR RESEARCH

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673, FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 12/13/2016

To: Hengyi Fu

Address:
Dept.: COLLEGE OF INFORMATION

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
A Life-Cycle Perspective on Community Dynamics and Developing Strategies in Successful and Unsuccessful Online Peer Production Communities

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and one member of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR Â§ 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 12/11/2017 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by
the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA00000168/IRB number IRB00000446.

Cc: Besiki Stvilia, Advisor
HSC No. 2016.19775

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673, FAX (850) 644-4392

RE-APPROVAL MEMORANDUM

Date: 12/12/2017

To: Hengyi Fu

Address:
Dept.: COLLEGE OF INFORMATION

From: Thomas L. Jacobson, Chair

Re: Re-approval of Use of Human subjects in Research
A Life-Cycle Perspective on Community Dynamics and Developing Strategies in Successful and Unsuccessful Online Peer Production Communities

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 12/11/2018, you must request renewed approval by the Committee.

If you submitted a proposed consent form with your renewal request, the approved stamped consent form is attached to this re-approval notice. Only the stamped version of the consent form may be used in recruiting of research subjects. You are reminded that any change in protocol for
this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report in writing, any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc: Besiki Stvilia, Advisor
HSC No. 2017.22657

Florida State University
Office of the Vice President For Research
Institutional Review Board
Human Subjects Office
humansubjects@fsu.edu/850-644-8673

RE-APPROVAL MEMORANDUM

Date: 1/11/2019

To: Hengyi Fu
Address:

Department: COLLEGE OF INFORMATION

From: Florida State University Institutional Review Board (IRB)

Re: Continuing Review Application

A Life-Cycle Perspective on Community Dynamics and Developing Strategies in Successful and Unsuccessful Online Peer Production Communities

Your request to continue the research project listed above involving human subjects has been approved by the Florida State University Institutional Review Board. If your project has not been completed by 1/10/2020, you must request a renewal from the IRB.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be
used in recruiting research subjects.

You are advised that any change in protocol for this project must be reviewed and approved by the IRB prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the IRB. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to ensure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protections. The Assurance Number is FWA00000168/IRB number IRB00000446.

Cc: []
HSC No. 2018.26331
REFERENCE


https://doi.org/10.1109/FLOSS.2007.9


https://doi.org/10.1145/2145204.2145270


human factors in computing systems (pp. 779–788). ACM. https://doi.org/10.1145/1518701.1518821


BIOGRAPHICAL SKETCH

Hengyi Fu is a Doctoral Candidate in Information at the Florida State University School of Information (Florida’s iSchool). She has an MS in Library and Information Science from the University of Illinois at Urbana Champaign, a MS in Information Technology from Hong Kong University of Science and Technology, and a BS in Management Information System from Nanjing University of Aeronautics and Astronautics in Nanjing, China.

Hengyi’s research is at the intersection of Online Communities, Knowledge Curation, and Social Computing. Her overall research aim is to integrate social science theories, quantitative and qualitative empirical methods, and computational techniques to understand and design socio-technical systems. Her research interests include computer support cooperative work, human-computer interaction, peer production, social computing, social media, human-computer interaction, cross-language information retrieval, information quality assessment. Hengyi’s web site is at https://fuhengyi.wordpress.com/.

JOURNAL PUBLICATIONS


PEER-REVIEWED CONFERENCE PAPER

PEER-REVIEWED CONFERENCE POSTER


RESEARCH AND TEACHING EXPERIENCE

Lead Graduate Instructor (varied courses) 8/2015 - 5/2019
School of Information, Florida State University, Tallahassee, FL

Graduate Teaching Assistant (varied courses) 8/2013 - 5/2015
School of Information, Florida State University, Tallahassee, FL

Research Assistant (with Dr. Shuyuan Mary Ho) 8/2014 - 8/2015
School of Information, Florida State University, Tallahassee, FL

AWARDS AND SCHOLARSHIP

- Esther Maglathlin Doctoral Research Scholarship, School of Information, Florida State University, 2017-2018
- ACM CSCW Student Travel Grant (Group), 2018
- ASIST SIG-USE Interdisciplinary Conference Travel Award, 2017
- ACM SIGIR Student Travel Grant (CHIIR), 2017
- Lewis-Marxsen Scholarship, School of Information, Florida State University, 2016-2017
• ACM SIGIR Student Travel Grant (JCDL), 2016
• Outstanding Teaching Assistant Award Nominations, Program for Instructional Excellence (PIE), Florida State University, 2014-2016
• Outstanding Doctoral Graduate Teaching Assistant, School of Information, Florida State University, 2014-2016