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Knowledge Creation and Innovation in the Virtual Community ? Exploring Structure, Values and Identity in Hacker Groups

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Abstract

The arguments in the paper demonstrate how the underlying community ideology, values and community structure initiates the collective knowledge creation and sharing practices in the GNOME community. Evidence suggests that it is on the basis of the community ideology that the group becomes a community of solutions waiting for problems to be broadcast. Principles of meritocracy and the identity and status of members as hackers are important characteristics that not only shape interactions and form the basis of participation, but also mobilise knowledge as participants move from the periphery to core, enabling them to become practitioners of the art.

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Introduction

The growth of the internet has led to the formation of new forms of social exchange, creating what are generically known as ‘virtual communities’ (Klang & Olsson, 1999). Virtual communities have received increasing attention in recent years. Numerous articles have emerged on virtual firms, organizations, and work teams. However there is little theoretical insight into the different ways that virtual communities can work. The hacker community provides one of the most intriguing examples of how virtual communities can be innovative on-line.

The paper provides a window into several aspects of the hacker community, analysing the theoretical implications for knowledge creation and innovation that characterizes one type of hacker community: the open source software (OSS) community.

We argue that the OSS community has certain characteristics regarding membership, purpose and its core-periphery structure that makes it useful to explore the applicability of the theory of Communities of Practice (CoP) to this empirical domain. By examining peripheral participation and distributed problem-solving, for example, we can understand critical conduits for knowledge transfer and sharing within the community.

The Hacker Community and Knowledge Creation and Innovation in Open Source

Software (OSS)

The growth of the internet has led to the formation of new forms of social exchange, characterised by reliance on technology, task/activity orientation, physical dispersion and irregular interaction (Hsu et al., 2007; Gupta and Kim, 2004) creating what are generically known as 'virtual communities' (Klang & Olsson, 1999). The hacker community provides one of the most intriguing examples of how virtual communities can be innovative on-line. Levy (1984) provides one of the earliest definitions of hackers, describing 'to hack' as an activity or project that is undertaken not just as an objective task but for pleasure and involvement. The core elements of the early 'hacker ethic' emerge from this point and include the creative use of technology, the inclination towards reverse engineering and a curiosity to explore systems (Taylor, 2005).

Open source software (OSS), developed by hacker groups, is considered to be one of the most promising new alternatives to monopolistic proprietary software. In contrast to the traditional form of innovation, advances in technologies have shifted the locus of innovation to particular user communities such as the open source software (OSS) community that are able to create software applications of superior quality as compared to commercial organizations (Fuller et al., 2004). The significance of OSS is reflected in both the degree of non-propriety that allows anybody to participate and the innovative capabilities that arise from an infrastructure that is independent of and different from proprietary forms.

In contrast to the view that innovation is supported by private investments from which private returns are appropriated (Von Krogh et al., 2003) – the logic and rationale for software development in corporate settings – the OSS community freely reveals and shares software codes. However, some kind of rent may be obtained from services and goods associated with the OSS programs developed (Fitzgerald, 2006). This suggests that there are elements of both the private and the collective model in the OSS innovation process. Von Hippel and von Krogh (2003) therefore advocate a private-collective model of innovation. They argue that while individual community members directly forego intellectual property rights and rents from their contributions, they may benefit in indirect ways from their investment in time and resources in the community. This may be through extrinsic reward for individual members or through the possibility of capitalising on the software produced by the community in other products or services associated with the software. Thus the private element is satisfied by the

use made of the product that has resulted from investment rather than using intellectual property rights to secure rents. This model proposes that free-revealing results in a net gain for the innovator through diffusion of innovation and the creation and utilisation of social networks (Von Hippel and von Krogh, 2003). It gives some insight why innovation works in the context of OSS, but its economic perspective focuses on the role of extrinsic incentives and underplays the intrinsic incentives and social aspects of the innovation process.

Some scholars (Meuit and Kogut, 2001; Von Hippel, 2001) have proposed that knowledge creation and sharing occurs very quickly in OSS communities due to the absence of spatial and geographical boundaries. Others have argued that social interactions and informal knowledge sharing due to the distributed nature of work are the mechanisms through which knowledge is created and shared in the OSS community (Koh and Kim, 2004). It is argued that members construct and share new knowledge through a peer review process and gradually contribute more, as they move from the periphery to core. Few studies have examined the structural and processual characteristics underpinning knowledge creation and innovation in OSS communities. This paper seeks to fill this gap by examining the link between knowledge creation and sharing and the process of innovation.

Communities of Practice and Innovation

This study draws on the concept of Communities of Practice (CoP) to examine how the OSS community develops explorative and exploitative innovative capabilities. The notion of CoP suggests that community boundaries involve practice and person based networks, where members are interwoven in the fabric of knowledge (Pan and Leidner, 2002). Lave and Wenger (1991: 98) described a CoP as "... a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice". They drew on the notion of apprenticeship to explain processes of knowledge acquisition and learning, viewing it as a form of socialisation into a community. The newcomer gradually becomes a legitimate member of the CoP through learning the community's accepted practices, its language and its conventions during processes of interaction with established members (Hildreth et al., 2000).

It is argued that too much exploitation can drive out exploration (Benner and Tushman, 2002), leading to core rigidities (Leonard-Barton, 1992) and competency traps (Levitt and March,

1988). On the other hand, too much exploration results in the neglect of adapting existing routines and the failure to optimise benefits from existing capabilities. Thus, maintaining balance between the two types of learning is a primary factor in sustaining innovation (March 1991). Organisations tend to drift towards exploitation as they mature, however some organisations may tend towards the opposite direction- too much exploration, the question of how virtual communities maintain this balance of exploration and exploitation through virtual CoP is the key question addressed in this paper.

The existing literature suggests that organisations may adopt structures (e.g. dual structures or semi-structures) or they may develop a culture or common identity (e.g. common language or shared background) that are conducive to simultaneous exploration and exploitation (Tushman and O'Reilly, 1996; Brown and Eisenhardt, 1997; Benner and Tushman, 2002; Gibson and Birkinshaw, 2004). There are other structural and behavioural factors that play a vital role in balancing the tensions between exploration and exploitation. Organisations may rely on spatial and/or temporal separation (Puranam et al. 2006). Through spatial separation, members work in distinct units.

In contrast temporal separation utilizes the same unit but at different times for either exploitation or exploration (Andriopoulos and Lewis, 2008). The need for differentiating and integrating exploration and exploitation is minimised as the same organisational units take on both types of activities at different times. Here the ability to fluidly and continuously alter the attributes of the organisation is critical to the strategy (Puranam et al. 2006; Brown & Eisenhardt, 1997). Behavioural factors are the social means of balancing exploration and exploitation. Lubatkin et al. (2006) argue that greater behavioural integration helps with the contradictory knowledge processes of exploitation and exploration and enable their joint pursuit. This requires combining elements of formal and informal organization in a unique manner to avoid the inconsistencies between exploration and exploitation, as 'hybrid arrangements' (Puranam et al. 2006). An example of such integration can be seen in Brown and Eisenhardt's notion of 'semi-structures' (1998) arguing that choices of structural and behavioural integration is not a reversible decision and that the existence of organisational hybrids such as 'semi-structures' need to be grown and not assembled in a single point in time (Brown & Eisenhardt, 1997: 31). The study presented in this paper explores the structural, cultural and behavioural factors underlying the virtual knowledge creation and sharing of the virtual innovative community.

Research Methods and Data Analysis

For a 'typical' case of OSS development, we selected the GNOME (GNU Network Object Model Environment) project as our central focus. It is one of the largest OSS projects involving around 500 members with a large archive of programs and libraries. The GNOME community was established in 1996 by a group of loosely coupled, globally distributed volunteer developers. They shared the objective of creating a desktop environment with a user interface, a set of applications comprising a spreadsheet, word processor and other easy-to-use applications, and a development framework comprising libraries, tools and components for the environment (German, 2003). Communication occurs mostly via the internet, through the Internet Relay Chat (IRC) and emails. The software development is centred on the CVS (Concurrent Version Control) system, bugzilla (the bug tracking system) and the GNU (a computer operating system) tool suite for software development (German, 2002).

The overall aim was to construct, from the ground up, a detailed and deep qualitative understanding of virtual innovation as a processual phenomenon (Meyers, 1997). In order to pursue these processual aims, we examined structural and behavioural factors that play a role in exploration and exploitation from the hackers' perspective, using semi-structured interviews (Orlikowski, 1993). In turn, this allowed us to construct a detailed case study of the OSS community.

The research project as a whole used the findings of the GNOME study as a starting point to examine OSS innovation within multiple embedded case study design (Yin, 1994) that allows both literal and theoretical replication (McClintock, 1979). Following initial in-depth interviews with one sample of GNOME hackers, we conducted a second phase of interviews with other GNOME respondents to enable within-case comparisons and theory elaboration. With third and fourth phase interviews with respondents in other OSS communities (e.g. KDE), we could make cross-case comparisons that further enriched our theoretical understanding of general OSS innovation processes.

Data collection and sample

Fifty Semi- structured interviews and non systematic observations were used to understand the stages the characteristics of community structure and knowledge sharing that have an

impact on the innovation process. Various OSS communities were chosen; GNOME (GNU Network Object Model Environment), KDE (K Desktop environment) and OSS members working in other related projects. The interview respondents were sampled according to the extent of their involvement with the community. More specifically the selection process was aimed at constructing a sample consisting of members who range from volunteers and paid developers to core participants such as board directors and marginal contributors at the periphery of the community. Most members are male in the age group of 19-36. Most members have a science degree and considerable years of involvement with OSS development. The face-to-face interviews were conducted at OSS conferences and recorded on tape. The 50 varied from one to two hours in duration and all were transcribed.

Each interview was conducted face-to-face, based on a semi-structured questionnaire and designed to develop first-order accounts of the innovation process within the community. The questionnaire was directly informed by key concepts and issues raised in the literature. Each interview gleaned data that could be iteratively tested within the field against later interviews and, as an accumulating database, allowed us to explore and establish basic patterns in the innovation process.

The 50 respondents were selected using a stratified sampling technique, giving access to individuals playing different roles within the community, including users, bug fixers, core developers and moderators, as well as those involved in non-technical financial, marketing and strategic activities. Information was obtained about background, project structure, motivation for joining, and technical characteristics of the project.

Member Profile	Position in the Community	Age/Gender	Education	Years of Involvement with OSS
Simos	Contributor/Maintainer	34/Male	PhD (Computer Science)	5
Jeff	Board of Director	37/Male	BA (Fine Arts)	12
Glynn	Board of Director	29/Male	BSc (Mathematics)	7
Demetris	Contributor/Maintainer	33/Male	Postgraduate Research (Computer Science)	5
Diego	Contributor	19/Male	High School	6
Bastien	Maintainer	30/Male	B.Sc (Computer Science)	13
Sayamindu	Contributor	20/Male	Undergraduate (Computer Science)	3
Johnathan	Board of Director	30/Male	B.Sc (Computer Science)	9
Havoc	Maintainer/Board Of Director	31/Male	BA (Anthropology)	11
German	Contributor	26/Male	B.Sc (Mathematics)	7
Carlos	Contributor	22/Male	Undergraduate (Computer Science)	2
Albetros	Contributor	23/Male	Undergraduate (Computer Science)	2
Quim	Board of Director	36/Male	BA (Journalism)	7
Isabel	Contributor	32/Female	BE (Software Engineering)	10

Table 1: Profile of Interviewees (Phase 1 GNOME, Birmingham Interviews)

Based on the understanding of the project structure from the first few interviews, the questionnaire was modified to gain an understanding of open source processes and characteristics based on the various roles played by community members. Information was also gathered about the nature and type of work, identity within the hacker community, communication patterns, and processes of contribution and governance mechanisms.

Member Profile	Position in the Community	Age/Gender	Education	Years of Involvement with OSS
Calum	Maintainer	27/Male	B.Sc (Computer Science)	5
John	Board of Directors	31/Male	B.Sc (Computer Science)	6
Rob	Founding Member	30/Male	MA (Mathematics)	10
Demetris	Contributor/Maintainer	33/Male	Postgraduate Research (Computer Science)	5
Simos	Contributor/Maintainer	34/Male	PhD (Computer Science)	5
Bastien	Maintainer	30/Male	B.Sc (Computer Science)	13
Christian	Maintainer	28/Male	B.Sc (Electronics)	8
Sami	Maintainer	26/Male	B.Sc (Computer Science)	5
Sabastien	Maintainer	30/Male	B.Sc (Computer Science)	8
Dave	Maintainer	34/Male	ME (Electronic Engineering)	13
Quim	Board of Director	36/Male	BA (Journalism)	7
Edward	Maintainer	34/Male	MA (Computer Science)	14
Stormy	GNOME Board Member	35/Female	BA (Computer Science)	12-15
Federiko	Founding member/Board of Director	31/Male	B.Sc (Computer science, discontinued)	15
Marina	Contributor	29/Female	ME (Computer Engineering)	5
Rafael	Contributor	22/Male	Undergraduate (Computer Science)	2
Gabriel	Contributor	22/Male	Undergraduate (Computer Science)	1
Travis	Contributor	24/Male	BA (Computer Science)	6
Kevin	Contributor	21/Male	Undergraduate	2

Table 2: Profile of Interviewees (Phase II GNOME, Turkey Interviews)

In Phase III, interviews were conducted in India. Members were largely maintainers or contributors to various OSS projects. With one exception, the respondents were male, and they fell within the age group of 21- 34 years, with Bachelor degrees in various engineering disciplines. Members' involvement in OSS projects ranged from 4 months to 15 years. This is as seen from Table 3.

<i>Member Profile</i>	<i>Position in the Community</i>	<i>Age/Gender</i>	<i>Education</i>	<i>Years of Involvement with OSS</i>
<i>Abhas</i>	Owner of an OSS firm	34/Male	Master (Computer Science)	15
<i>Ramakrishnan</i>	Contributor to various OSS projects	30/Male	Master (Computer Science, discontinued)	10
<i>Biju</i>	Maintainer for Linux	34/Male	Architect	15
<i>Issac</i>	Contributor (GUI)	26/Male	Bachelor (Mechanical Engineering)	6
<i>Jalaknarayan</i>	Contributor (startup OSS projects)	26/Male	B.Sc (Computer Application)	6
<i>Abhijit</i>	Contributor (GNOME)	28/Male	Bachelor (Industrial Production Engineering)	8
<i>Venkat</i>	Contributor (OpenSolaris)	31/Male	Bachelor (Manufacturing Engineering)	3
<i>Gopi</i>	Contributor (OpenBSD)	34/Male	Bachelor (Computer Science)	5
<i>Pradeep (KDE)</i>	Maintainer and Liaison officer	32/Male	Diploma (Computer Science)	8
<i>Akash (KDE)</i>	Contributor	23/Male	Bachelor (Engineering Physics)	2
<i>Narayan (KDE)</i>	Maintainer	27/Male	PhD (Computer Engineering)	6
<i>Shanmu (KDE)</i>	Contributor	21/Male	B.Sc (Mathematics)	2
<i>Gopala (KDE)</i>	Contributor	29/Male	Bachelor (Information Science Engineering)	4 months
<i>Kapil (KDE)</i>	Maintainer	33/Male	Bachelor (Chemical Engineering)	7
<i>Vima (KDE)</i>	Contributor	26/Female	Bachelor (Computer Engineering)	4
<i>Raghav (KDE)</i>	Contributor	20/Male	Bachelor (Information Technology)	1

Table 3: Profile of Interviewees (Phase III KDE and members of other communities)

Data analysis

The data were analysed using well-known approaches to inductive studies (Glaser and Strauss, 1967; Miles and Huberman, 1984; Yin, 1989). 'Narratives' from the respondents were organised around specific questions, allowing for flexibility and modification during the progression of the analysis, integrating evidence from different elements of the data (Yin, 1981). Responses were transcribed into a database indexed by the constructs of the interview

guide. Through an iterative process, the data were revisited as important features of the innovation process emerged.

It is important to note that each respondent's narratives were first analysed separately to identify his or her experiences of the process through which the innovation unfolded and of the structural characteristics that facilitated the process. When rounds of re-analysis no longer yielded new structural and processual themes, the researcher's emerging second-order account of the innovation process was checked across the British and Indian sub-samples for new conceptual insights (Miles and Huberman, 1984). Initially the cases were compared and common themes were identified. Reduction tables were constructed to facilitate further comparisons between the two sets of interviews, identify similarities and differences between the sub-samples, and elaborate emerging constructs and theoretical reasoning.

The most problematic feature of the research reported in this paper is its dependence on retrospective accounts of past process (Soulsby and Clark, 2011). We have taken the normal precautions to add confidence to the presentation of the arguments – such as interviewing horizontally and vertically within the community in order to examine the process from different standpoints. Moreover, within a virtual community characterised by high levels of diversity in relation to role, nationality and geographical location, the many accounts of the innovation process show high levels of consensus that are unlikely to have emerged over time from intensive social relationships. As the project unwound, it became clear – though not reported in this paper – that accounts of innovation from different OSS communities and collected using different methods revealed the same or very similar process patterns, further increasing confidence in the arguments.

Main Findings

The study finds that the innovative capability of the OSS community lies in its core-peripheral structure, hacker culture and values and identity formation. This is made possible by the dynamic interface between the core and peripheral members, the norms/ideology governing the behaviours of community members and the attributes/motivations of individual members as aspiring hackers, the distinctive nature of the OSS community that encourages chaos, creative destruction and conflict. Through encouraging behaviour, often considered deviant in

commercial organisations, this virtual community is able simultaneously to generate and share knowledge through exploration and exploitation.

a) Exploration: The role of core and periphery of the community

Our findings suggest that individual contributions are shifting within the hacker community. The core and periphery of the community are not structural impositions but emerge through the nature and extent of contributions; members who contribute extensively are simply regarded as core while other types of assistance, such as providing patches and fixing bugs, are regarded as peripheral contributions.

The periphery is very large with varied degrees of contribution and also includes ad-hoc contributions from software organisations. The presence of such porous boundaries at the interface of the community and software organisations is of significance as it enables cross-fertilisation of knowledge, critical for the pursuit of both exploration and exploitation.

So we have about maybe 30 to 50 maintainers... And it's a very small group because one of the fascinating things about open source despite the enormity of the communities, the bulk of the work is actually quite a small group of ultra specialists. And that's another unique thing about Gnome as we have this really interesting company community collaboration. So you know it's sort of like 30 people on the very, very core and then there's the other sort of maintainers and contributors... and then everyone who can commit to CVS. Then beyond that there's people who are associated with the project in a somewhat more substantial way than just being users... They provide patches or provide bug triaging things like that... (Jeff: Board of Directors)

Peripheral members are not taught the 'know-what' through the process of apprenticeship. Further the notion of periphery is not simply in the sense of a social structure but has a temporal and spatial dimension to it, as situated learning takes place in the virtual environment as opposed to learning from face-face interactions. Peripheral participation is of significance as it contributes to the breadth of the knowledge base in the process of knowledge generation. Through such a large pool of peripheral participation, core members

are supported in their innovation activities. Movement from the periphery to the core is gradual, often through the process of self-learning, particularly in learning skills that are not technical in nature.

You know when you start it's not like this. When you start you read more news and you follow how other people work, you don't contribute yourself. And then you slowly start getting involved... (Demetris: Contributor)

The following remark illustrates the spatial and temporal dimension to contributions made by members.

When I receive say an email from my mailing list it then that will tell me to make some contribution or to do something. (Simos: Contributor/maintainer)

Peripheral participation is of significance as it contributes to the breadth of the knowledge base in the process of knowledge generation. Through such a large pool of peripheral participation, core members are supported in their innovation activities. These peripheral members are actively engaged in the practices of the core members through a shared ideology.

Movement from the periphery to the core is gradual, often through the process of self-learning, particularly in learning skills that are not technical in nature.

It was a hacker only community until a few years ago but now if you look what people is doing there's not only coders. And beyond these people that are coders realize that they alone cannot go much further because at some point you have normal people and you have to deal with them and you need more skills than just coding... (Quim: Board of directors)

Such self-learning facilitates the development of knowledge related to exploratory forms of innovation. For convenience we refer to such knowledge as 'exploration-based knowledge'. Such knowledge is tacit in nature and creates 'knowledge asymmetries' as members' perceptions and cognitive capabilities are different. The following remarks reveal such asymmetries in knowledge contributions, often generated by a meritocratic social structure.

... we have different degrees of contribution to so many projects...email like very small contribution to a specific project... informing them of some mistake...So I would say I'm contributing in different degrees. But we have like different levels of contribution... (Simos: Contributor/Maintainer)

... between 1 and 2000 people have commit access to the Gnome software repositories. So they might be developers or translators, because translators commit the translation directly in. But then you have people who contribute through our bug tracking system and although they might not commit, they might not have that privilege, they often file... (Jeff: Board of Directors)

Self-learning and searching for information are key characteristics of new and peripheral members, as contributions are embedded in the social context. The search for knowledge has repercussions for knowledge creation and transfer because it is linked to the presence of strong and weak ties at the core and periphery.

I'm a little stopped by knowledge... I have been learning from people that I work with and they like to teach you because they are not giving away their work or their knowledge. They are creating the people that tomorrow will help them or replace them or its going to be their employees... (Diego: Contributor)

Self-learning facilitates the development of knowledge related to exploratory forms of innovation. The ad-hoc peripheral contributions highlight the importance of chaos in the early stages of the innovation process. These unsystematic contributions made by peripheral members enable the community to pursue exploration, because members enjoy the freedom and flexibility to develop new knowledge and acquire new skills. Thus, peripheral contributions are instrumental in the creation of a flexible community architecture that establishes the foundation for exploration-based knowledge development.

Problem solving also appears to be a mechanism of initiation for new members. Through finding solutions and tinkering with facets of software code that do not work, there is a gradual transformation from peripheral contributions to more sustained forms of involvement. This promotes non routine knowledge creation and such transitions from the periphery to the rim of the core increases the knowledge flows across the boundaries

I had a modem which didn't work properly in Linux... And getting it to work was a pretty difficult task at that time. So, I somehow managed to get it to work and thought that I would document that. And what happened was as soon as I documented the entire thing and published it on the web, further people – two people contacted me and said why you don't put it in the Linux documentation project. So, that's how I got started.

And the first – I joined the community but I wasn't very active. Probably the first interaction with the GNOME community I had was when I wrote a review – not a review exactly, a preview article for an upcoming GNOME release... But people in the GNOME community reacted quite positively to it. So, that gave me encouragement and so I started to become more and more involved in mostly not programming but writing stuff, taking interviews of people... And I also got involved in a project called the GNOME Journal, which is a magazine run by volunteers about GNOME... At the same time in a parallel fashion I was also involved – I started getting involved in the localization project for my own language... (Sayamindu: Contributor)

Thus, the switching of roles within the periphery and across the boundary from the periphery to the core suggests that the shifting composition of members results in the novel and unexpected interactions of contrasting perspectives that contribute to the development of exploration-based knowledge that is responsible for radical innovation; although there is spatial and temporal discontinuity at the periphery, there is temporal continuity at the core of the community which remains constant throughout the project cycle. The permeable structure of the community ensures that participants contribute gradually to more specific tasks and the various layers of the community are temporarily tied together for the completion of a release cycle.

In sum, our findings indicate that members of the virtual community are not taught the know-what and peripheral members are actively involved in the community. Further, there is evidence of a movement of members from the periphery to the core of the community through

self learning and searching for information or solutions which lead to the development of exploration based knowledge.

b) Exploitation: The norms and ideology of the hacker community

The OSS community is dependent not on individual contributions but on a constellation of practices. It is driven by individual user needs but sustained by a community that goes beyond just providing solutions for problems in that it opens up new venues for learning, particularly for members at the periphery.

Some members join the OSS community to be able to unravel the mystery of software programming and to develop an understanding of the structural and processual mechanisms of the operating system. The underlying beliefs and the community's representation of freedom attract participants from various streams of software programming.

Then I started to get to know some project like Genome, Linux and some others. Since I used some of them, I get to know that how the community works. I started to get interest in being part of this community... I like the idea behind all these stuff like in Genome, the philosophy of symbol ... (Diego: Contributor)

And then I started using it, playing with it, I keep tinkering a lot more because it was open source... later on I kept on using Linux, using different desktops, and I become very interest in GNOME because it provided the whole range of applications, and pretty good at the time... (Bastien: Maintainer)

When members join, their contributions are often sporadic and less critical to the project, however such contributions are significant because they set the stage for future involvement. As members find their niche and begin to realise their potential, they become aware of external knowledge, assimilate such knowledge and apply it, thus creating a common 'knowledge pool' for the benefit of the community.

As one member notes:

So, and I found open source, with open source I found that I was able to do this and that. So, I was able to follow the development of best software better and it was more adventurous this way. So, it's like your home I guess... (Demetris: Contributor/Maintainer)

These contributions enable the community to gain benefits from exploration based knowledge, which can be transformed into 'exploitative knowledge' during the later stages of the innovation process.

As joiners become more deeply involved in problem solving, their contributions take on a degree of formalisation, which constricts the exploration activities. The attention of such members, who progressively move into the core, is gradually directed towards task specific aspects of the search processes.

As the movement of members is based on meritocracy, the introduction of this mechanism of problem solving becomes the starting point for the codification of the best practices, thereby making the exploration based knowledge easier to exploit in the other stages of the software development process. This also signifies the beginning of the social division of labour in the community. As evident in the above interview excerpt, by gradually allowing members to move to the core, knowledge is progressively organised around specialist tasks, bringing in highly specialised knowledge.

The above accounts provide some understanding of the process through which members become involved in the community and their progression from the periphery to core.

As one member notes:

First they are ignored then it's just staying... Then they were regarded as a hassle. Then they are laughed at, then people realize that what they have to contribute is worthwhile and... No. It's... we don't have a really clear mentorship kind of process or anything like that... I am joking about all of that but there is an element of truth that's funny because that's true because it is hard to get involved in Gnome, because of all positives of that fluidity, have an impact and it's hard to find out where to start. (Jeff: Board of Director)

The core team of maintainers tends to remain in its position for a longer period of time. There is a general absence of clear job descriptions and designations are often taken on by the members themselves. As a result of fluid boundaries, members often take on roles based on their individual ability to contribute and thus choose modules based on their own needs.

There is a practice of switching roles, often facilitated by self learning, through which collaborations and relationships evolve from distant acquaintances to colleagues.

I also used to maintain a set of Bengali fonts but at the stage – after a certain stage I found out that I wasn't being very active there. So, I stepped down and someone else is maintaining it... So, there you need to have a few features like you might not want the user to be able to configure everything. So, that process is called lockdown where you limit certain actions that the user might take. So I'm kind of – there is already a lockdown framework in GNOME but I'm trying to enhance that... (Sayamindu: Contributor)

Changes in roles suggest that there is gradual convergence in the community as activities progress from a random distribution of ideas to putting these ideas into practice and testing them out. There is also a shift in patterns of trust – as trusted members get access to code repositories where the code can be changed without having to go through the maintainer. From the interviews, a recurrent and common theme that emerges is the presence of different modules and teams.

But it's like a bit of experimentation like people working in many different ways like trying different routes and then sees whether they will work. So, there is a lot of ways to achieve the goals... (Simos: Contributor)

I'm like a general contributor. I try to fix whatever I see broken. Of course what I can fix because there is people that can fix the more complicated than what I fix. I try to promote it in Genome besides being a code contributor right now I'm part of the account team that creates the accounts for new developers to work directly on the source code that it create, I get you help there how source code is managed in projects... (Diego: Contributor)

The findings indicate that the peripheral member activities are shaped by the modules in which they are embedded. Through an explicit and extended search process by peripheral members, they discover opportunities in particular modules, often with limited prior experience.

This discussion highlights the mechanism of problem solving through which new members who join are able to integrate gradually with the community. As members become more and more integrated through deeper involvement in problem solving activities, their contributions become more task specific, transforming the exploration-based knowledge to exploitative knowledge.

c) Switching between exploration and exploitation: The attributes and motivations of individual members reinforce the ability of the community to flip their activities and prevent too much exploitation or too much exploration.

The findings above indicate that there is a practice of switching roles, often facilitated by self learning, through which collaborations and relationships evolve from distant acquaintances to colleagues. Thus, the switching of roles within the periphery and across the boundary from the periphery to the core suggests that the shifting composition of members results in the novel and unexpected interactions of contrasting perspectives that contribute to the development of exploration-based knowledge that is responsible for radical innovation; although there is spatial and temporal discontinuity at the periphery, there is temporal continuity at the core of the community which remains constant throughout the project cycle.

Social practices such as meritocracy that underlie the process of exploration and exploitation are grounded in the ideological beliefs of the community. Such practices are backed by the philosophy of gaining from the community and contributing back to the community. Evidence suggests that it is on the basis of the community ideology that the group becomes a community of solutions waiting for problems to be broadcast. Principles of meritocracy and the identity and status of members as hackers are important characteristics that not only shape interactions and form the basis of participation, but also mobilise knowledge as participants

move from the periphery to core, enabling them to become practitioners of the art and to be able to rapidly switch between exploration and exploitation.

The OSS community is dependent not on individual contributions but on a constellation of practices. It is driven by individual user needs but sustained by a community that goes beyond just providing solutions for problems in that it opens up new venues for learning, particularly for members at the periphery. The underlying ideology of the community initiates the knowledge creation and sharing process and explains why experienced members spend time in assisting new members.

I first learned about it from the ideological perspective... When I do something I want to solve a problem, I want to do it for as many people as possible. I don't want people to get back to the thing that I had to do. So, it's a better way to spread that solution... (Havoc: Contributor/Board of Directors)

There is no formal mechanism through which new members are formally assisted by experienced members in integrating with the community. The process of integration often occurs through problem solving. Problem solving is the social mechanism that drives the innovation from the phase of conceptual development to the creation and development of prototypes. The GNOME community can be visualised as a 'community of solutions' waiting for problems to be broadcast, because of the varied skills that members bring through their specialised contributions and learning by doing. This is analogous to the Garbage can model of organisational choice (Cohen et al., 1972). Further, shifts in technology, fluid participation and a lack of coherent structure give rise to an assortment of ideas within the community. Thus in the GNOME community there is a continuous interplay of streams of problems and solutions and the choice of solutions is dependent on the stage of innovation, whether the community is exploring or exploiting.

The identity of members shapes the knowledge creation process and at times the knowledge creation process gives members an identity, because, through contributions, they strive to achieve the status of a hacker. Its connotation within the confines of the community is prestigious and symbolises a ranking that is based on merit, a distinction between those who write software code and those who hack – a term attributed to members with more skill and greater involvement within the community.

It doesn't feel right you go around saying I'm a hacker or I feel like a hacker. It's usually something that someone else will give to you... a lot to the other guys that are actually more of a hacker than me... (Simos: Contributor/Maintainer)

As one novice contributor notes:

I like to call myself a hacker but sadly you can't say that on loud voice because people are going to think, "Oh you're a hacker, you're going, can you give me the software from that guy?" No, I'm not that kind of hacker, that's a cracker. But I like the idea behind the work that you like to play with stuff, you like to investigate, that's part of my personality... (Diego: Contributor)

Such a system of meritocracy also creates mobilisation of knowledge, as much of the knowledge generated at this stage is exploration based knowledge, which is largely tacit and internalised. The concept of 'becoming a hacker' helps us to understand individuals' personal stakes and how they are related to attaining core membership in the community. It is evident that becoming a hacker is not only a form of CoP but is also tied to the structural and processual aspect of the innovation process, as it enables members to become 'practitioners of the art'. This is because the motivation to engage with the community and dispositions towards OSS are developed during the course of the experience of becoming a hacker. Further, this is also a process of socialisation, which often begins with members being new to the community at the start and achieving the status of a hacker in the end (Bergquist and Ljungberg, 2001).

Through the process of becoming a hacker, members are able to solve problems in an unconventional manner while being able to 'tweak' the code. Tweaking, or playing with the code, also enables externalisation to occur, thereby creating knowledge mobility. Following are insights from core as well as peripheral members.

I'm not giving back; I wouldn't like to work on that. Because I like the part of the philosophy giving back, you take but you also give back... (Diego: Contributor)

A hacker is somebody who can tweak and fiddle in an interesting way, in a noble way, somebody who can come up with the solution... I was working quality

assurance for a few a, for a few mobile operators in the U.K.... it would install the software, run test, that we couldn't do anything about and then results at the end of the week. And the next week we would do it again with another version of the software. And we had no way to go inside the, go inside the application and see what it was doing, we didn't even know if it was supposed to work better or work worse each week. It was completely blocked out and it was so frustrating...

(Bastian: Contributor/Maintainer)

The social practices such as meritocracy that underlie the process of knowledge creation are grounded in the ideological beliefs of the community. Such practices are backed by the philosophy of gaining from the community and contributing back to the community. Members believe in the development of solutions that are not just relevant to a particular situation but for the larger benefit of the community; such a mechanism of problem solving is deeply embedded in the ideology of the GNOME community. Members attribute an intrinsic moral value to the software developed.

This underlying ideology enables the community to overcome the knowledge-technology gap that lies between simply using a software tool and understanding it. In proprietary software quality assurance, teams only run tests on new features and can only test different versions of the software, whereas, based on these OSS ideological principles, one can get inside the application and observe what exactly occurs.

These arguments demonstrate how the underlying community ideology initiates the collective knowledge creation and sharing practices in the GNOME community. Evidence suggests that it is on the basis of the community ideology that the group becomes a community of solutions waiting for problems to be broadcast. Principles of meritocracy and the identity and status of members as hackers are important characteristics that not only shape interactions and form the basis of participation, but also mobilise knowledge as participants move from the periphery to core, enabling them to become practitioners of the art.

Conclusion

This paper has sought to get inside the black box of how Knowledge Creation and Innovation in the Virtual Community is achieved through exploring Structure, Values and Identity in Hacker Groups. Our findings support the view that the OSS innovation process works because of the structure of the community and the values and identity of hackers that allow the community to go through exploration and exploitation phases both sequentially and simultaneously. This paper has rehearsed these arguments in detail through a summary of the GNOME case study findings and it has extrapolated the significant theoretical lessons about what makes virtual innovation possible.

Semi-structured interviews highlighted the way in which virtual innovation unfolded around phases of divergence and convergence. We discovered that the structural and processual features of the GNOME community had significant implications for knowledge, problem solving and learning activities through which it sustains high levels of innovative capacity.

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