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Communities of practice, knowledge acquisition and innovation: a case study of science-based SMEs

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ABSTRACT

Purpose – Recent research into communities of practice (CoPs) has focused on large organizations, suggesting they can be constructed for the purposes of knowledge acquisition and innovation. The study provides evidence that for small science-based firms CoPs are more likely to emerge unplanned to support incremental innovation in the form of problem solving activities.

Design/methodology/approach – Thematic template analysis was used to analyze 25 in-depth interviews conducted with a range of employees in science-based SMEs.

Findings – Analysis of the interview data from a case study of seven science-based SMEs provides evidence that both intra and inter-organizational CoPs were leveraged for a variety of purposes, including the acquisition of knowledge and improving firm's ability to generate innovative solutions.

Research limitations/implications - Whilst there cannot be any claim of 'representativeness' of the sample in relation to the wider population of science-based firms, the authors do maintain that the new empirical material has made a contribution to a research area which has been dominated, especially in recent years, by a focus upon large organizations that have adopted a managerialist orientation.

Originality/value - The challenges of understanding the role of CoPs in science-based SMEs and the factors that influence their success, or otherwise, have not been sufficiently investigated and have received little attention in the extant literature. Hence, this paper makes an original contribution to this body of knowledge.

Key words - Communities of practice, innovation, knowledge acquisition, template analysis.

Paper type – Research paper.

1. INTRODUCTION

The research project upon which this paper is based is concerned to understand whether, and if so, how, science-based SMEs engage with CoPs in order to acquire new knowledge and whether any innovations are generated through such engagement. The project addresses a number of specific questions relating to CoPs in science-based SMEs:

1. Are CoPs to be found such organizations?
2. If so, how and why do they emerge and/or are they constructed?
3. How is knowledge acquired?
4. What innovations, if any, are generated thereby?

The study extends our understanding of CoPs in science-based SMEs through the new empirical material the authors have gathered and the development of a framework for constructing CoPs in science-based SMEs.

2. COMMUNITIES OF PRACTICE

In knowledge management (KM) terms, a community of practice is a group of people informally bound together by shared expertise and a passion for a joint enterprise (Wenger and Snyder, 2000). The initial theoretical formulation of CoPs (Lave and Wenger, 1991) focused on the way in which individuals learn, and argued that learning is socially situated, that is, it arises from and within the context, activity, and culture in which it is developed and used. CoP theory has been adapted by knowledge management theorists and used to highlight its value in relation to increasing firms' absorptive capacity, i.e. the ability to recognize the value of new, external information, assimilate it, and apply it to commercial advantage (Cohen and Levinthal, 1990), improve learning (Autio, et al., 2008) and innovation (Assimakopoulos, 2007; Scarbrough, et al., 2004).

The emergent and self-selecting membership features of CoPs can contribute to strategy and innovation, help start new lines of business, solve problems on the spot, transfer best practice, develop professional skills and help the recruitment and retention of talent (Wenger and Snyder, 2000). Through the sharing of practice participants learn together, focusing on problems directly related to their work (Wenger and Snyder, 2000). This has some affinity with Orr's (1996) ethnographic study of photocopy repairmen, although Orr used the term 'occupational communities' (Van Maanen and Barley, 1984) rather than CoPs.

Lave and Wenger's (1991) and Wenger's (1998) earlier CoP research failed to acknowledge that a lot of research and technological development work is now done between organizations-these early formulations being rather amorphous, group-centric and inward looking (Assimakopoulos, 2007). CoP theory has often ignored the inter-organizational networks and relationships that are required in complex, technology-rich, innovation-driven organizations, where research and development is organized and conducted at distributed locations (Assimakopoulos, 2007). Moingeon et al. (2006) argue for the support and development of inter- organizational communities of practice (IOCoPs), noting that such CoPs can bring together professionals belonging to different organizations and that 'for the organization, IOCoPs indirectly represent a powerful monitoring and innovation force, making both knowledge production and distribution easier' (Moingeon et al., 2006, p.13). Similarly, Allee (2000) comments that if CoPs emerge in the social space between project teams and knowledge networks they could be beneficial in supporting learning communities that extend both inside and outside organizational boundaries.

For science-based SMEs wishing to innovate, there are two clear imperatives: support the development and circulation of knowledge within and pursue alignments across CoPs. Innovation occurs both within and across the boundaries of business firms, universities,

research laboratories, suppliers and buyers (Moingeon et al., 2006). 'Open innovation' in particular involves searching outside the firm's boundaries for mutually beneficial relationships (Chesbrough, 2003), and focuses upon how firms manage their network of internal and external relationships (Dahlander and Gann, 2010). Open innovation has increasingly emphasized the role of communities in creating, shaping and disseminating innovations (Fichter, 2009). Autio et al. (2008) argue that firms involved in collaborative innovation should purposely foster the development of CoPs. There are clear links between open innovation and absorptive capacity, particularly with reference to the sourcing and exchange of externally developed knowledge (Vanhaverbeke et al., 2008). CoPs may provide an introductory vehicle for SME knowledge management (Du Plessis, 2008), a means to boost technological learning, and a means to commercially exploit new innovations (Autio et al., 2008).

Notwithstanding the above, the authors and others have found that, for science-based SMEs at least, the construction of CoPs can be problematic. It is unlikely, for example, that SMEs can spare the resources required for constructing CoPs (Roberts, 2006). These resources can include time for CoP participation, training for CoP leaders, and IT tools to facilitate participation in CoPs (McDermott and Archibald, 2010). Given that they have access to fewer resources than larger organizations, Tödtling (2001) suggests, however, that they might compensate precisely by engaging in CoPs to support innovation and knowledge management (see also Partanen et al., 2008). Probst and Borzillo (2008) advocate the use of 'governance committees' to assess the activities of CoPs and management sponsors to guide them, but such practices might be seen by SMEs to divert resources away from core business activities (Pattinson, Preece and Scott, 2011).

In the next section the authors briefly outline the research methodology and case study organizations.

3. METHODOLOGY

The research project used the critical case sampling technique to identify and select cases relevant to the research questions (Patton, 2002). This helped to generate the four science-based SMEs, access to which was negotiated and agreed between key gatekeepers in these organizations and one of the authors. Semi-structured interviews were conducted with 21 individuals employed in technical (i.e. scientists and engineers) and commercial roles (i.e. operations, finance and purchasing). The interviews lasted for between 40 and 80 minutes and were audio- recorded with the permission of the interviewee, and subsequently transcribed verbatim. The names of the organizations and interviewees have been anonymized for confidentiality reasons. Template analysis (see Crabtree and Miller, 1999; King, 2004) was used to thematically analyze the resultant data. This deploys hierarchical coding, beginning with broad a priori themes, moving to sequentially narrower, more defined themes as the analysis progresses. This method was chosen because it is in sympathy with the adopted social constructionist epistemology, and was used, inter alia, to explore relationships, the meanings attributed to actions, and the various perspectives and orientations of the interviewees.

Nvivo qualitative data analysis software was used to code the data and create the final thematic template. Nvivo was helpful in organizing and storing the data as well as generating a hierarchical structure. It also supported an iterative process, allowing for codes to be added, deleted or changed more readily than a 'cut and glue' paper-based approach; it did not, however, replace the iterative process of generating codes, which is where Template Analysis came in. This, argues King (2006), is a flexible, iterative methodology that facilitates a

systematic yet reflexive approach to data analysis. Appendix 1 lists the themes which emerged during coding. Whilst the authors' sample is not claimed to be representative of the wider population of SME science-based firms, it does present new empirical material on CoPs, knowledge acquisition and innovation in such organizations, an area where there has been only a limited amount of research to date. The six organizations are now briefly outlined.

Company A is a contract chemical processing company providing bespoke outsourcing solutions to the process industry, such as agrochemicals, biocides and herbicides. It is the largest and longest established of the six firms. Company B manufactures a range of in-vitro diagnostic products for use in the detection, prevention, and monitoring of medical conditions related to haemostasis and platelet function. Company C is a university spin- out, manufacturing semi-conductor materials in the cadmium telluride family, which have a variety of applications in medical imaging, security screening, industrial inspection and space exploration. Company D specialises in the design and manufacture of gas sensors and analyzers and provides solutions to gas monitoring in a variety of environments. See Table 1.

Table 1 about here

The following section presents and discusses the findings.

4. FINDINGS AND DISCUSSION

The findings are presented and discussed below in relation to the four research questions.

4.1 Are CoPs to be found in science-based SMEs?

Wenger (1998) claims that CoPs exist in all organizations, but most research into CoPs and innovation have focused on large businesses, which prompted this first research question. The data reveals three types of CoPs present in these science-based SMEs – apprentice-based CoPs, intra-organizational CoPs and inter-organizational CoPs.

In Company B there was evidence of apprentice-based, which emerged to support individual learning and internal knowledge-sharing related to individuals' domain of scientific knowledge. Junior scientists moved from 'novice' to 'master' and, through their participation as CoP members, in the process gaining the firm-specific scientific knowledge that they needed to participate in innovation activities:

> [Name omitted], our R&D Manager, he, and our other less experienced scientists, through [the MD's] mentoring really, is getting in touch with this and that group of people and the knowledge is transferring to [R&D Manager] so he is getting more confident in passing this on to colleagues. (Technical Manager, Company B).

Intra-organizational CoPs were leveraged for a variety of purposes including individual learning, internal knowledge-sharing, and for supporting noncanonical practices. Scientists and engineers pooled their expertise in problem- solving activities. These CoPs emerged through such mechanisms as 'corridor meetings', and shared many similarities with Orr's (1991) study of a community of photocopy repairmen. As one participant commented: 'people work in teams generally, but often the most productive solutions happen by accident, like when we chat at lunch about formulations... we discuss possibilities'. In Company D,

intra-organizational CoPs were constructed through the use of a boundary object, the 'Imagineering Wall', which was used to encourage informal collaboration and stimulate innovation. This is not dissimilar to the CoP cultivation approach adopted by the organizations in Probst and Borzillo's (2008) study. The 'Imagineering Wall' was a large tri-divided whiteboard mounted on an office wall, where employees posted ideas for new products or improvements to existing products. Employees were encouraged to post ideas on the wall, no matter how bizarre they might appear, in order to encourage sharing and creativity and an open approach to innovation:

> It was the idea of open sharing of ideas within the company, sort of, that anybody, wherever they work in the company, can submit any idea they have, and it can go on the wall… and everyone else can see it… and everyone else can contribute. (Design Engineer, Company D).

The company did not keep records of each employee's informal 'wall activities' until these became designated as formal projects. This meant that an employee could move from one project to another without informing anyone and, therefore, he/she might be engaged in multiple CoPs at any one time.

Inter-organizational CoPs (cf. Moingeon et al., 2006) emerged between SMEs and two distinct sets of customers: commercial organizations, focused on developing new products and processes, and R&D organizations represented by universities and other research organizations seeking to commercialize their inventions. These CoPs were particularly evident in Companies B, D and E. One interviewee commented on the importance of regular contact for building and maintaining strong relationships with customers through informal contact: 'We very much have to work with these customers and build relationships, and that can only be achieved through regular contact' (Managing Director, Company B). Recurring

interaction with customers produced a sense of shared understanding. By working together towards a mutual goal and engaging in a joint enterprise, inter-organizational CoPs emerged, where the participants sought to develop innovative solutions in partnership with customers:

> We work together with the customer to provide solutions in a way we both understand. Someone may call, a chemist or engineer for example, or someone else... call to discuss progress, and that's significant in terms of maintaining good relations and meeting their demands for a solution. (Operations Director, Company A).

The leveraging of personal relationships helped bring people together, including customers, competitors and suppliers. In Company B, the MD had built an extensive inter-organizational CoP consisting of diverse members, including hospital doctors, nurses, GPs, practice managers, hospital technicians and academics. It appeared that an important ingredient in the success of such inter-organizational CoPs was the strength of the (bridging) social presence of a particular individual or individuals, in this case the MD of Company B. Social presence has been found to be associated with successful community building (Rovai, 2002), and has some resonance with Coakes and Smith's (2007) notion of 'innovation champions' who transcend organizational boundaries and support collaboration with other communities and organizations. Company B had been particularly successful at building external connections and, as the R&D scientist acknowledged: 'Well I suppose it's 'who you know' - especially who [the MD] knows as he's worked in the industry a long time'. The MD in this instance exhibited a particularly high level of saliency in both his networking and relationship-building. An example of CoPs emerging between SMEs and their suppliers can be taken from the interviews in Company A, which held occasional events for their suppliers in order to encourage informal knowledge sharing:

> … we invite major suppliers here … and we will give them, if you like, seminars on different sort of process techniques, which sort of can help them go and find more businesses… and has a reciprocal effect in that they put us in touch with businesses who want help… sort of knowledge [sharing] (Managing Director, Company A).

There were a number of references in the authors' case study interviews to mutual engagement, shared repertoires, and joint enterprises between these SMEs and their customers and suppliers.

In the next section the authors explore how and why these CoPs were constructed.

4.2 How and why are CoPs constructed in science-based SMEs?

CoPs in science-based SMEs in this study were found to be an essentially emergent phenomenon. There was also some evidence of attempts to cultivate CoPs. The use of boundary objects (such as the 'Imagineering Wall' in Company D) stimulated the cultivation of multiple intra-organizational CoPs. The 'Imagineering Wall', for example, brought together scientists and engineers who, through the building of shared repertoires, mutual engagement and joint enterprise, formed a variety of CoPs focused on both incremental (improving existing products) and radical innovation (developing 'new to the world' products). There were implementation problems, however. For example, some employees felt that they could not always use the 10% time allocated to become involved in projects that interested them. Others highlighted the fact that, once they had posted their initial ideas on the wall, they struggled to generate new ideas:

> It's a good idea… when it was first developed because everyone had been sitting for a few years saying "why didn't we do this", "why didn't we do that"… and when the wall was put there everyone just jumped on it… and everything is discussed and

> bashed out… and then, after the novelty is worn off everybody's sort of got rid of their ideas and it is now sort of sat… we don't really have enough external stimulation to keep it going… (R&D Engineer, Company D).

The wall initially acted as a boundary object, encouraging practice-based creativity, but in order to maintain momentum and help generate new innovative 'big ideas', the organization perhaps needed to move beyond capturing the skills, expertise and creativity of its employees and seek to create or join external, inter-organizational, CoPs. Other efforts to cultivate CoPs included building and maintaining trust-based relationships and credibility with customers - closely linked to developing reciprocal relationships. Building trust was essential in order to facilitate effective knowledge sharing and to help SMEs to better understand their customers' needs - as Field (2008) has observed, 'relationships matter'. Through mutual engagement, sharing expertise internally with colleagues and externally with customers and suppliers, SMEs were able to build effective trust-based inter-organizational CoPs, thus generating social capital, developing their capabilities and improving their ability to problem solve on behalf of their customers. This finding is in contradistinction to Hamburg and Marin (2010), who argue that SMEs are unreceptive to knowledge sharing due to a lack of trust.

Trust was found to be an essential ingredient for building social capital in inter-organizational CoPs, and the SMEs employed a variety of trust- building activities to engage customers and suppliers. For example, Company A held free seminars to which they invited their customers and suppliers, whereas Company B provided free specialist advice to a university. These companies used such events to build trust and stimulate informal networking. The inter-organizational CoPs that developed in the aftermath of such events frequently led to more formal partnerships being established between firms, often based on a mutual need for expertise not possessed internally. These organizations, by offering on-going advice and support, and thus sharing their expertise, were able to encourage informal interaction between

members of different cognate organizations, which sometimes formed the basis of inter-organizational CoPs. The establishment of trust between members of the different firms was linked to building credibility with customers. Some larger SMEs, notably Companies A and E, encountered similar difficulties when engaging in trust- building activities, and on occasion adopted a pragmatic approach in order to source external expertise. For example, for Company C, which was engaged in radical innovation in developing new products, trust-building could be a secondary consideration after identifying someone with the necessary expertise, particularly if the person was not within their existing external network. However, overall, the study found that SMEs were able to build external trust-based collaborative relationships and, CoPs sometimes developed through regular mutual engagement with customers. This helped them to better understand their customers' needs and provide appropriate solutions.

Reciprocity was an important part of the trust- building process and was often achieved through offering free advice or additional services. Companies A, B and D all offered their services free to both commercial and R&D customers. Company A provided free services to commercial customers in order to maintain regular, informal contact, build collaborative relationships and generate future business. For non-commercial customers, e.g. universities, these reciprocal arrangements often led to informal knowledge exchanges and the emergence of inter-organizational CoPs. As the MD of Company B commented:

> … in the past [N] university's got a grant to do this research, then we say 'well, we'll do this', but then that's how we got the contacts, so 'cause we've done this, or that for them, if we want something to be externally validated, we can say, you, 'Do you mind doing this?' (R&D Scientist, Company B).

The relationship here was cultivated by the MD of the company. Entrepreneurs such as these, who displayed high levels of social presence, were able to build strong, long-lasting, trust-based relationships. The ability to 'be out there' making connections was an essential factor in building successful inter-organizational CoPs, based on trust and reciprocity. Thus, the knowledge exchanges that occur in CoPs are an essential part of the innovation process in science-based SMEs; in the next section the authors discuss how this knowledge is acquired.

4.3 How is knowledge acquired in science-based CoPs?

As has already been seen, internal and external knowledge acquisition is a key part of the innovation process for science-based SMEs. Individual learning was often informal and both apprentice-based and intra-organizational CoPs emerged in response to the need to support the sharing and dissemination of knowledge. Apprentice-based CoPs emerged to support members' needs to expand their existing scientific knowledge and they thus often supported informal 'on the job' training and development. Although individual learning was recognized as being important for innovation, the view of managers was that it had to be aligned with the firm's commercial goals. This could inhibit the emergence or cultivation of CoPs by restricting the knowledge domain:

> We might have to do bits of research, but the learning for learning's sake… or because of what's interesting, isn't really what we do. We are a commercial company and we need to make products, we need to make money. That's what we're in it for. We're not in to widen everyone's understandings… (New Technology Manager, Company C).

The individual learning that occurred in the apprentice-based CoPs in Company B was more aligned to notions of incremental innovation, where there is a high level of reliance on building a shared repertoire that facilitates the passing on of existing scientific knowledge

internally between CoP members. Conversely, for the SMEs involved in radical or disruptive innovation, such as Company E, the emergence and/or cultivation of apprentice-based CoPs was inhibited by the absence of a shared repertoire, which in turn was related to a lack of a shared domain of knowledge in a particular field of scientific research where there was a high level of novelty or uniqueness associated with the innovation. As one interviewee observed: 'We're not doing projects that are digging ditches or building walls'.

Both the emergent and cultivated CoPs which focused on specific domains of scientific knowledge were seen to support knowledge sharing between various professional groups, such as scientists and engineers. Members of these CoPs participated in a range of knowledge- sharing activities, including what one interviewee called 'the obvious stuff', as well as things they 'didn't yet understand'. The impetus for this was often a wish or need to support members in problem- solving activities conducted on behalf of customers. This is illustrated by an interviewee's reference to informal 'corridor meetings' with colleagues in Company C, where internal knowledge exchanges often occurred. CoP members pooled their expertise, participating in problem solving activities, a kind of incremental innovation, on behalf of customers:

> Internally, there is a network, which is probably the four people who I talked about, you know, the IT guy, the detector guy, myself and Ben, and that's an informal network, you know, but we're… we tend to do corridor meetings, you know: 'how's that?' … our Venn diagrams of influence cross over so regularly.. (Materials Manager, Company C).

It is important to note, however, that the construction of CoPs could be inhibited. In Company C, for example, the Chief Technical Officer commented that for senior scientists occupying strategic roles in SMEs, it was often difficult to access intra-organizational CoPs

due to a lack of ‘band width’ inhibiting their capacity to build CoPs relationships and leverage the social capital necessary for innovation. CoP participation became more difficult because they could not maintain regular contact with their network of scientific colleagues. Additionally, conflict frequently emerged between scientists and engineers, the former viewing innovation as a ‘journey’ whilst the latter saw it more in terms of a ‘destination’. This sometimes restricted the emergence of intra-organizational CoPs. In general, scientists were considered to be less commercially aware than engineers, who were more focused on developing an end product:

> An engineer wants to get somewhere. In fact an engineer’s happy if something never happens again, you know I think that’s the thing that… a scientist likes to do a thing over and over and over, you know, ‘we’ll try that’, ‘I’ll do that experiment’. An engineer’s target, I would say, is to make it to have nothing to do in a day. (Technical Manager, Company C).

In SMEs focused on radical innovation, i.e. Company E, this conflict inhibited knowledge-sharing activities generated through the emergence or cultivation of CoPs, thereby restricting their ability to turn innovations into commercial products. The literature suggests that in networks people might fear losing their expert status, whereas organizations might fear disclosure of their competitive knowledge, thus questioning whether organizations are willing to initiate innovation projects with new partners (Wohlfart et al., 2006). SMEs in particular might refrain from participating in such innovation networks because of the perceived increased risk to their competitiveness (Meeus and Oerlemans, 2000). However, Meeus and Oerlemans (2000) observe that the limited resource base usually available to small firms does not negatively impact on innovativeness as they are able to develop the adaptive behaviour conducive to innovation.

The present study found that collaboration was an essential part of the commercialization of innovation for all the SMEs for a variety reasons, including sourcing external scientific expertise from other firms and universities, seeking commercial expertise to help them exploit their innovations, as a route to market through licensing agreements, and as a source of funding. At the same time, customers often sought collaboration with SMEs to acquire external knowledge. Companies A, B and G in particular used this approach to bind customers to them, in effect cultivating an inter-organizational CoP by building a shared repertoire through regular, informal contact. There was much evidence of the internal pooling of expertise and exchanges of tacit knowledge through collaborative activities, often resulting in or from the emergence of CoPs. SMEs acted as 'key experts', solving problems on behalf of their customers, and there was evidence of enhanced absorptive capacity based on SMEs' collaborative activities with customers.

The capability to access internal and external pools of knowledge suggests that although these SMEs may have no formal strategy for knowledge acquisition, they did possess some absorptive capacity based upon the collaborative relationships that develop through emergent CoPs (see also Beijerse, 2000):

> Right at the outset they'll [customers] come to us and say, 'Look, we've got a particular problem. Do you think you can solve it?' And, coming back then to the pool of knowledge and experience we have within the business, then we can apply ourselves and we can usually come up with solutions, or recommend alternative solutions… but, you know, we can either develop... bring in outside expertise or pass perhaps potential enquiries on to other people that we know or source solutions from people in our network. (Operations Director, Company A).

The SMEs which were collaborating predominantly with R&D customers tended to value collaborative trust-based relationships more than those mainly working in partnership with commercial organizations. For the former, collaboration with universities was an important source of external scientific knowledge, as well as providing access to research and development funding and specialist scientific equipment and facilities. The latter tended not to consider themselves innovative; although they engaged in collaboration with customers, they were generally suspicious of, or failed to see the value in, collaboration with other external organizations. This suggests that those SMEs who see themselves as engaged in innovative activities tend to be more aware of the importance of collaboration and are also more likely to actively seek collaborative relationships, engaging in the CoPs that emerge through shared repertoire and joint enterprise, focused on their specific scientific domain of knowledge.

In summary, the findings illustrate how science-based SMEs acquire internal and external knowledge through the construction of, and participation in, CoPs. CoPs support individual knowledge acquisition and improve absorptive capacity, both of which are necessary for successful innovation. In the next section the authors discuss the impact this participation has on their innovation activities.

4.4 What innovation is generated from collaborative activities in CoPs?

The findings of this research suggest that in relation to radical innovation, the construction of CoPs is inhibited by a lack of shared repertoire, especially for those science-based SMEs at the forefront of their respective scientific field. The literature indicates that participation in intra-firm knowledge sharing activities is often difficult because it is dependent on CoP members' willingness to voluntarily share their knowledge and expertise (Hildreth and Kimble, 2000; Kogut and Zander, 1996; Von Hippel, 1998; Von Krogh et al., 2000; Wenger

et al., 2002). The findings support the view that CoPs are more likely to support incremental innovation in science-based SMEs.

For SMEs working with R&D organizations, innovation was often described in terms of novelty or uniqueness, i.e. aligned with ideas of radical or disruptive innovation and verified by 'new to the world' products and processes. The SMEs working with commercial customers considered innovation more in terms of 'problem solving' activities, i.e. aligned with views of incremental innovation, evidenced by collaborative activities as problem-solvers for their customers. The SMEs involved in producing novel innovations sometimes found it difficult to engage with external organizations because the uniqueness of the knowledge base associated with their innovation resulted in the lack of a shared repertoire. In effect, the SMEs were frequently the 'knowledge leaders' in their particular field. Although novelty provided capability advantages, some interviewees considered it a barrier to collaboration: 'We are the only people in the world doing this… innovation is quite difficult 'cause it can only come from ourselves' (Material Manager, Company C).

This finding suggests that for SMEs generating novel innovations, their status as 'knowledge leaders' restricts their ability to engage in inter organizational CoPs because of a lack of shared repertoire. However, some interviewees in Company E, generating novel innovations, were aware that further incremental innovation, often generated through collaborative activities, was required in order to successfully commercialize their inventions. A lack of shared repertoire restricted their ability to engage in informal networks, or in the informal collaborative relationships that often result from CoP participation. Nevertheless, there was collaborative relationship- building and the emergence of shared repertoires through mutual engagement with a range of external organizations, including customers, suppliers and competitors.

Tension was noted between scientists and engineers regarding their views of innovation. At one extreme, there were scientists who said they sought to discover entirely new processes and knowledge. At the other extreme, there were engineers who used their knowledge to build useful devices. In general, scientists viewed innovation as a 'journey' and appeared to be less commercially aware than engineers, who were more focused on developing an end product. In those SMEs focused on radical innovation, the level of conflict between scientists and engineers was often more pronounced because of the absence of a shared repertoire. This was related partly to a lack of common existing knowledge, but also because of the uniqueness or 'novelty' associated with radical innovation. This aspect sometimes inhibited the internal knowledge- sharing activities associated with the emergence or cultivation of intra-organizational CoPs. On the other hand, these same SMEs, in particular Company C, generally found it easier to collaborate with R&D customers, such as universities, and there was evidence of both resource sharing and knowledge sharing through inter-organizational CoPs.

> We still collaborate with the university… in fact we built a system… one of the four systems is at the university, you know, so we have a fairly strong collaboration with [D] University. We work with their scientists on a variety of crystal growth development... issues... we can dip in and out of each other's research quite often, almost by accident. (Technical Manager, Company C).

The interviewees expressed a range of views about innovation per se. Those who saw their firm's innovation activity as being towards the radical end of the spectrum generally considered their firm's products and processes to be unique. Others saw the innovation activity in more incremental terms, e.g. offering 'better' solutions by making a product simpler in order that customers find new uses for it. Uniqueness was considered a source of competitive advantage to the SMEs, who were often operating in niche markets. However,

interviewees also recognized the importance of engaging in incremental innovation in order to develop new products based on their initial science-based innovation, or when they were commercializing their innovations. Although novelty or uniqueness was considered a capability advantage, the lack of shared repertoire (which, as we have seen, is usually generated through mutual engagement) restricted the community- building activities associated with inter-organizational CoPs.

Interviewees in Company A did not consider their organization to be innovative because it did not manufacture its own products; those in Company D expressed a similar view because they created new products by integrating existing technology rather than through their own R&D activity. However, the Imagineering Wall had been successful in generating a number of small incremental innovations to existing products; the CoPs that emerged from the associated activity had produced 6 new versions of products that were on the market, and a further 4 projects were in the early stages of development (as at July 2013). Given these organization's incremental approaches to innovation and their problem- solving activities on behalf of or in partnership with customers, one can see many similarities with the sort of 'user-led' innovation communities discussed by Heiskanen et al., (2010) and Von Hippel and Finkelstein (1979), which, the authors would argue, are in essence a form of inter-organizational CoP.

Problem solving requires in-depth collaboration and, as these examples show, SMEs share knowledge with their customers in order to develop complex innovative solutions. They use a variety of methods to engage with customers, including hosting events to showcase their expertise and visiting customers to offer advice and training related to their products. Thus customers were sometimes reliant on the sharing of scientific expertise with the SMEs, and this required individuals from the organizations to work closely together, engaging in

problem solving activities and generating the mutual engagement and building of shared repertoires necessary for inter-organizational CoPs to emerge.

5. CONCLUSIONS

5.1 Findings

The empirical findings of this research project confirm the existence of CoPs in science-based SMEs and show how they emerge or are cultivated for a variety of purposes, including knowledge acquisition and innovation. This confirms the widely held view in the extant literature that CoPs exist in most organizations (Brown and Duguid, 1991; Hildreth et al., 2000; Lesser and Prusak, 1999; Wenger, 1998; Wenger et al., 2002). Three types of CoPs were identified: apprentice-based CoPs that support individual learning; intra-organizational CoPs that facilitate internal knowledge sharing (particularly between different professional groups, e.g. scientists and engineers); and inter-organizational CoPs that emerge between SMEs and external organizations (e.g. customers, universities), and were leveraged to support a range of collaborative innovative activities. However, the SMEs did not always recognize either the presence of CoPs or the benefits they might gain from explicitly engaging in their construction. The findings also identified instances where, although the conditions for constructing CoPs were present (there was mutual engagement, shared repertoire and joint venture), CoPs did not emerge. This suggests that science-based SMEs could do more to develop and support the cultivation of CoPs.

5.2 Limitations

Although template analysis is a useful tool for analyzing qualitative data, issues arose in relation to its use in this research project. Deciding on the extent of the initial template and the number of codes was a necessarily subjective process, potentially leading to accusations of researcher bias. In order to mitigate such bias, the data was coded, discussed and reviewed at various stages by the authors. Although this provided some consistency in terms of

applying the template method, it did not allow for the inclusion of multiple perspectives. Involving a wider range of reviewers, or even involving the interviewees themselves, might have generated some insights when developing the template. Sampling bias: these science-based SMEs represented a heterogeneous group of firms from a range of scientific disciplines. However, they had science at the core of their business and, therefore, could be argued to represent a variety of typical, although not necessarily representative, cases that were useful in generating data and making comparisons and contrasts.

Whilst the authors cannot make any claim for the representativeness of the sample in relation to the wider population of science-based firms, they do maintain that this new empirical material and theorizing on CoPs and innovation in science-based SMEs makes a contribution to a research domain which has been dominated, especially in recent years, by a focus upon large organizations and (where publications have drawn upon new empirical material) there has been an over-reliance upon the voice of senior managers (as against, for example, scientists and engineers). In the next section the authors present a contextualized framework for the construction of CoPs in science-based SMEs.

5.3 Implications

The contextualized framework for constructing CoPs (Figure 1) shows how science-based SMEs can promote CoP construction. The framework captures how intra-organizational CoPs can be promoted by SMEs by first identifying existing and potential CoPs and then encouraging their construction by allocating time and resource to their cultivation. Inter-organizational CoPs can be promoted by SMEs by encouraging employees to mobilize their personal networks and by firms taking part in, as well as organizing, networking events. SMEs should also encourage individuals who display high levels of 'social presence' to act as brokers and boundary spanners, drawing external knowledge and expertise into the

organization, and thus enhancing their firm's absorptive capacity. SMEs which pursue these sorts of activities and take these sorts of initiatives can thereby encourage and support CoP cultivation, and thus build trust and reciprocity, leading to enhanced social capital. Participation in intra-organizational CoPs increases firms' absorptive capacity; participation in inter-organizational CoPs stimulates open innovation (see also Chesbrough, 2003). This helps SMEs to build new networks and facilitates more effective knowledge transfer, thus helping to generate more focused innovation in science-based SMEs.

Figure 1 about here

5.4 Suggestions for future research

The findings provide a number of insights and pointers for future areas of research. Firstly, whilst it was not possible, given the time constraints of the current research, to conduct a longitudinal study, this would be helpful for examining in more detail, inter alia, the types of CoP activities taking place and how they change over time, along with the (changing) membership of the CoP. Secondly, future research would benefit from a larger sample size to establish a better understanding of CoPs in science-based SMEs. Thirdly, this research focused on the views and experiences of managers, scientists and engineers- it would be valuable to gather the views and experiences of a wider range of people, both internal and external to the focus organization.

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Table 1 The science-based SMEs

Firm	Employees	Turnover	Industry/ Sector	Type of CoP(s)	Purpose of CoP(s)
A	80	£5 million	Chemical processing	Inter-organizational	Problem solving on behalf of commercial customers
B	14	£1.2 million	Biotechnology	Apprentice-based Inter-organizational	Passing on existing scientific knowledge/supporting incremental innovation Problem solving on behalf of commercial customers
C	60	£2.4 million	Semiconductor manufacture	Intra-organizational Inter-organizational	Internal knowledge sharing between scientists and engineers focused on radical innovation External knowledge sharing between scientists and engineers focused on radical innovation
D	40	£5.2 million	Gas analyzer equipment	Intra-organizational	Internal knowledge sharing that supported incremental innovation

Figure 1 A framework for constructing CoPs in science-based SMEs