A later version of this paper appeared in Creativity and Innovation Management

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A user community-based approach to leveraging technological competences: An exploratory case study of a technology start-up from MIT

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Acknowledgements: We thank Karin Eckmair, Markus Frank, Raffaela Fromwald, Petra Hollerer, Thomas Isamberth, Cherilyn Knaupp, Martin Kober, Christof Miska, Roman Pickl, Sabrina Reiter, Petra Selner, Shuai Wang, Daniel Winzer, and Silvia Zahradnik for their support in data collection and data analysis. Furthermore, we thank RallyPoint, Inc. for providing the case and the editor and two anonymous referees for their input.

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Abstract

Many studies highlight the impact of technology commercialization on innovation and wealth creation (e.g. Shane, 2004). However, this impact could be far higher, especially as many technologies developed with high costs and effort still remain vastly underutilized. One important reason for this problem can be found at the front end of the technological competence leveraging process: Searching for market opportunities for a technology is a formidable challenge (e.g. Herstatt and Lettl, 2004). In many cases, alternative fields of application (or even a single viable market opportunity) for a given technology are simply unknown to the entity in charge of commercialization.

Based on an extensive literature review, we identify two major shortcomings at the front end of the technological competence leveraging process which contribute to the underutilization problem: 1) the local search behavior of the commercializing entity and 2) the use of solution-based instead of problem-based search specifications.

On the basis of these insights, we discuss the potential role of user communities in the search for (additional) market opportunities for a given technology, a process usually referred to as technological competence leveraging (Danneels, 2007). We then empirically explore a user community-based approach in an illustrative case study with a start-up from MIT. Our findings show that when users were included in the search process, (1) the number of potential markets in which the technology could be applied was five times higher, and (2) more far-distant application areas as well as application areas previously unknown to the technology holder were reached. In addition, we discover design principles for a user community-based search process, providing practitioners with a hands-on guideline for employing a user community-based approach to technological competence leveraging.

Introduction

It is a straightforward and well-known economic argument that a firm's innovativeness heavily affects its business performance (Porter, 1990; Schumpeter, 1934). Interestingly, many studies on the importance of an organization's ability to engage in innovative activities focus on the introduction of new products or processes (Damanpour, 1996; Kleinschmidt and Cooper, 1991; Hurley & Hult, 1998). In other words, innovation often seems to be associated with the generation of new solutions to existing problems previously identified in the marketplace. However, this kind of activity, which is often referred to as a 'market-pull' approach, might not always be the best way for every organization to maximize business performance (Mowery and Rosenberg, 1979). Recent empirical work has shown 'technology-push' innovation strategies to have a higher positive impact on firm performance as compared to market-pull approaches (Kirchhoff et al., 2007; Walsh et al., 2002)[1]. In the case of technology-push strategies, the starting point for the innovation is a technology looking for applications that might serve as viable business opportunities (Chidamber and Kon, 1994; Herstatt and Lettl, 2004; Utterback, 1971).

The current economic crisis has generated increased interest in 'technological competence leveraging', a specific kind of technology-push innovation approach (Danneels, 2007). As the development and marketing of new technologies based on pre-identified customer needs are rather costly activities with uncertain returns on investment (Cooper, 1990), more and more organizations reduce the funds devoted to new R&D efforts. Instead, they are focusing on their existing assets and trying to extract additional value from former inventions and technologies by applying them to completely new markets (Jolly, 1997; Shane, 2004). The advantages of technological competence leveraging are obvious: Finding and evaluating new applications in which a pre-existing technological solution meets certain user needs is less costly and risky than developing and marketing a completely new product or technology from scratch (Ying et al., 2007; March, 1991). However, thinking about alternative uses for technologies or technological competences is not only advisable for large-scale enterprises which possess a huge stock of patents. Research organizations or start-ups which have invented radically new technologies might also benefit greatly from the ability to systematically search for and evaluate different fields of application. Gruber et al. (2008) recently confirmed that the likelihood of a technology start-up's success increases with the identification of *multiple* market opportunities before deciding which opportunity to pursue first. Entrepreneurs who identify and compare multiple market opportunities prior to initial

[1] Note: This does not imply that relying on 'technology push' alone will be beneficial to an organization. From the literature on organizational learning (e.g. March 1991, He and Wong 2004), it is well known that maintaining an appropriate *balance* between exploration (of emerging markets and technologies) and exploitation (of stable markets and technologies) is a key factor in an organization's survival and prosperity. In a similar vein, striving for an optimal combination of developing problem-based solutions and leveraging the potential of existing solutions/technologies should be of high strategic importance.

market entry are better prepared to focus on the most attractive market opportunity (Gruber et al., 2008).

Despite the high potential of technological competence leveraging (Jolly, 1997; Shane, 2004; Danneels, 2007), most patents and technologies owned by companies or transfer organizations in the university context remain underutilized (Friar and Balachandra, 1999; Herstatt and Lettl, 2004; Thomke and Kuemmerle, 2002; Wadhwa, 2007). This fact is partly attributed to a lack of managerial support for organizations intending to employ technological competence leveraging strategies (e.g. Danneels, 2007; Henkel and Jung, 2009; Herstatt and Lettl, 2004). There are only few proven tools or guidelines to advise technology owners on how to conduct a search for applications, which is a challenge in itself (e.g. Herstatt and Lettl, 2004) and is often heavily constrained by 'local search behavior' (Stuart and Podolny, 1996) and other barriers. For example, Shane (2000) showed empirically that entrepreneurs tend to identify market opportunities which were either already known to them in the past or are closely related to their existing stock of knowledge.

The contribution of this paper is twofold: First, we reflect on current approaches to technological competence leveraging and discuss the specific shortcomings which limit their effectiveness. Second, drawing on the results of an exploratory case study, we propose a novel approach to the identification and evaluation of new applications for existing technologies. The basic idea of this approach is to integrate user communities into the search for alternative fields of application. Existing research indicates that users are frequently able to recognize technologies as solutions to their specific problems and to come up with applications not envisaged by the manufacturer (DeMonaco et al., 2006). Based on these observations, the authors suggest building on recent knowledge about user-centered search methods in order to overcome the problem of local search bias in efforts to identify multiple market opportunities for a given technological competence. Therefore, the following research questions are explored: (1) How can communities of current and potential users be integrated in the identification and evaluation of alternative applications for existing technologies? (2) How effective is a community-based approach to technological competence leveraging in overcoming 'local search bias'? Additionally, the authors wish to shed some light on the specific conditions which may affect the success of such community-based approaches to technological competence leveraging.

The remainder of this paper is organized as follows: The next section provides a short overview of traditional approaches to technological competence leveraging and their inherent limitations. We then proceed to introduce the idea of integrating user communities into the process of systematically identifying alternative applications for existing technologies. After pointing out the potential advantages of involving user communities in such activities, we report on the findings of an exploratory case study conducted with the RallyPoint, Inc., a start-up founded by MIT students/alumni. The purpose of the case study was to generate a framework to help organizations employ user communities in the search for alternative applications as well as to explore the effectiveness and potential limitations of such an approach. Finally, we present conclusions based on insights from this exploration as well as opportunities for future research.

Traditional approaches to technological competence leveraging and their major shortcomings

The strategy of searching alternative market opportunities for existing technologies in order to gain a competitive advantage is not new, but it has certainly seen a great deal of attention in the recent past. In 1959, E.T. Penrose recommended looking at companies as a set of specific resources, arguing that certain corporate assets – like labor, capital and land – might serve as the basis for a wide range of potential services and should therefore be regarded as key drivers of a company's economic wealth (Penrose, 1959). The same is true of an organization's technological competences and know-how. Most technologies are likely to be valuable in many different applications (Danneels, 2007; Gruber et al., 2008; Mahoney and Pandian, 1992; Penrose, 1959; Teece, 1982 and 1986; Trott and Cordey-Hayes, 1996). As Teece puts it, "...a firm's capability lies upstream from the end product – it lies in a generalizable capability which might well find a variety of final product applications". Thus, discovering possible applications of a fungible technology is widely regarded as an activity of high importance to organizations a) trying to increase their return on previous R&D investments (Danneels, 2007; Fiet, 1996; Hayek, 1945; Stiger, 1961; Zahra and George, 2002) or b) trying to identify the most promising market opportunity for a new invention (e.g. Gruber et al., 2008). Research dealing with technological competence leveraging strategies roughly distinguishes between company/inventor-centered approaches and technology-centered approaches. Both types of approach (which will be presented in the sections that follow) suffer from different shortcomings and contribute to the evident underutilization of existing technologies (Friar and Balachandra, 1999; Herstatt and Lettl, 2004; Seaton and Cordey-Hayes, 1993; Thomke and Kuemmerle, 2002).

Company/inventor-centered approaches

There is a broad stream of literature which points to the importance of search processes for the identification of new business opportunities (Fiet, 1996; Hayek, 1945; Stigler, 1961). Empirical studies have shown that a systematic search is far more likely to lead an entrepreneur to a viable business opportunity compared to mere entrepreneurial alertness (Fiet, 2007). For example, successful entrepreneurs are distinguished from others by the fact that they actively search for, identify and evaluate multiple market opportunities for a technology prior to initial market entry (Gruber, et al., 2008).

However, knowledge about *how* the process of searching for multiple market opportunities is carried out is scarce and not very operational. Of the few existing approaches to systematically searching for and evaluating new applications for existing technologies, one of the best known is Souder's (1989) "total systems approach to technology push". This approach consists of eight interrelated steps that can be summarized in three major phases: The goal of the first phase is to reveal the technology's unique features and the user needs they might satisfy. The second phase is referred to as 'embodiment' and comprises all activities necessary to maintain a 'user mentality'. This phase aims to integrate the demand-side perspective in the technological competence leveraging process and comprises the actual internal search (based on the creativity of the company/start-up team members) for potential application fields. The third phase deals with the evaluation of the application fields identified (Souder, 1989).

Souder's approach – as well as others – illustrates one interesting aspect: In the traditional perspective, technological competence leveraging has been regarded as an activity that basically falls within the scope of the manufacturer's responsibilities. As described above, analyzing the benefits which can be derived from a given technology as well as generating ideas for new applications and evaluating them is usually done *within* the confines of the company (Souder, 1989). Potential users or customers are primarily consulted in order to validate previous assumptions. This internal, company/inventor-centered view is still the dominant paradigm in search-based approaches to technological competence leveraging.

The problem of local search behavior

Although it seems reasonable to search for additional applications for existing technologies by drawing on the inventors' knowledge, ideas and networks, such a strategy is likely to limit the success of technological competence leveraging efforts. The problem with this approach is that drawing exclusively on internal expertise might block organizations or inventors from finding truly new application ideas. For example, Shane (2000) showed empirically that entrepreneurs tend to identify market opportunities which were either already known to them in the past or are closely related to their existing stock of knowledge. Other studies on university technology transfer also have shown that over 70% of licensing partners are found via the social network of the inventor (or the group of inventors) (e.g. MIT Technology Licensing Office, 2007). A somewhat similar effect has been observed in the field of corporate new product development. Lilien et al. (2002) have shown that new product ideas generated exclusively in-house suffer from a lack of novelty compared to new product ideas which stem from external stakeholders (in this case lead users).

At the organizational level, this phenomenon is also known as local search bias (Rosenkopf and Nerkar, 2001; Stuart and Podolny, 1996). The adjective 'local' refers to the fact that search activities tend to relate closely to prior search activities. The downside of local search is that focusing on existing expertise can prevent the organization from exploring more distant solutions to innovation-related problems (Fleming and Sorenson, 2004; Helfat, 1994; March, 1991; Martin and Mitchell, 1998). In general, local searches usually lead to the identification of local optima instead of global optima (e.g. Rosenkopf and Nerkar, 2001), with the latter being far more important to overall firm performance and increasingly difficult to attain using local search methods, especially given rising complexity (Fleming and Sorenson, 2001).

The search for alternative applications for existing technologies can be regarded as a 'problem' which is structurally similar to new product development. In both cases, the task to be performed is to generate new combinations of means and ends in the sense of linking an invention to a market opportunity (Pearson, 1990). In new product development, the challenge is to come up with a novel technology (means) for a given application or purpose (end). In technological competence leveraging, the task is to search creatively for new purposes (ends) for a given technology (means) (Danneels, 2007; Herstatt and Lettl, 2004). Because of their 'local search behaviour', companies and independent inventor networks face serious problems in generating ideas for applications that differ greatly from the current market application(s) with respect to the context of use. They will – very often unconsciously – simply not consider potentially promising applications outside of their domain-specific knowledge. Thus, local search bias has to be considered a major reason for the untapped commercial potential of university as well as corporate inventions. Overcoming this problem and moving beyond local searches by expanding the search space seems to be an important prerequisite for finding highly novel re-combinations of knowledge, potentially more valuable opportunities as well as a greater set of market opportunities from which to choose (Arora et al., 2001; Gruber et al., 2008; March, 1991).

Technology-centered approaches

As an alternative to company/inventor-centered searches for additional fields of application, technology owners might decide to follow the more (and often rather passive) technology-centered approach. The idea behind this approach is to make a solution-based description of the technology available and accessible for a large number of potential users with heterogeneous personal, educational and professional backgrounds and to hope that someone will recognize the technology as a solution to one of her specific problems. Instead of internally searching for alternative applications, technology owners thus rely on the 'entrepreneurial alertness' of potential users in the case of technology-centered searches (Kirzner, 1985; 1997, a & b; Kaish and Gilad, 1991).

This approach to technological competence leveraging is not new: A classic example would be the case of laser technology, which was developed in 1960 by Theodore Maiman, a physicist with Hughes Research Laboratories. Maiman had developed an operational device of his Rubin Laser without having any idea of where to apply his invention. At Hughes Research Laboratories, the technology was referred to as a 'solution looking for a problem'. While the laboratories stopped funding the further development of the laser, Maiman published a detailed description of the Rubin Laser in 'Nature'. Shortly after the publication, scientists from different domains all over the world began to rebuild the Rubin Laser and to explore potential applications, making the laser one of the most important technologies and the basis for many applications in consumer electronics, information technology, medicine, military technology and many other fields (Townes, 2007). Similarly, Danneels (2007) identified this approach in his extensive case study of a technology company, as an interview with the director of new products illustrates.[2] Today, most organizations which employ technology-centered approaches in order to identify applications for existing technologies make use of online marketplaces for technologies. They either use brokering platforms like yet2.com that allow different companies to publish their patents and more or less detailed descriptions of their technological competences, or they launch an online directory of their technologies themselves (like P&G's 'connect + develop' platform, which allows users to browse the group's assets). All of these slightly different approaches have one problem in common: the use of solution-based search specifications.

The problem of solution-based search specifications

The rather passive technology-centered approach to leveraging technological competence has been shown to be a very ineffective way of identifying alternative fields of application (e.g. Arora et al., 2001; Lichtenthaler and Ernst, 2008). Lichtenthaler and Ernst (2008) state that in general, the success rate of relying on Internet marketplaces for technology has been relatively low with regard to the number of technology transactions initiated, particularly in comparison with the hopes initially placed in those marketplaces.[3] The major problem limiting the success of this approach is the use of solution-based search specifications: The description of the technology presented to the broad public is usually written from a very technical standpoint, or a patent letter is issued. The company which owns the technology emphasizes attributes and performance aspects of the technology that are important from their point of view. Thus, the owners very often communicate features instead of benefits, leaving the cognitively challenging tasks of understanding the main benefits of the technology as well as linking it with a potential market entirely to the future users (Arora and Gambardella, 1994; von Hippel, 1994). Although at least some (expert) users might be able to perform the activity

[2] "Well, we purchased a list of names of subscribers to Research and Development Magazine, which are researchers that are doing anything from aerospace engineering to food engineering, and mailed them a brochure that explained it. . . . We put together a brochure that said, 'We have this wonderful technology, INERT, and it can be used for many different things. Do you have any use for this? If you do, contact us and we'll work with you to develop products.' If you look at the brochure, it's very simple, easy reading. There are maybe six pages with a lot of pictures and ideas of how the product can be used." (Danneels, 2007, p. 521)

[3] According to the industry experts surveyed in Lichtenthaler and Ernst (2008), the most severe deficit of Internet marketplaces is that the commercialization of technology through these platforms constitutes a relatively unsystematic approach because it does not address specific technology customers. Furthermore, offering a technology through the Internet is also a relatively passive approach. A thorough presentation of the technologies is essential in order to generate interest from potential licensees. Given these resource requirements, many firms argue that the time needed to identify technology customers can be put to better use in other – more proactive – commercialization channels. Thus, the identification of a technology still requires a creative element by matching the particular technology with the application envisaged by the person searching the marketplace.

of revealing the potential benefits of a technology and linking them with benefits in the marketplace (DeMonaco et al., 2006), most potential users will fail to do so because of solution-based search specifications.

The reason for the rather poor performance of potential users in coming up with new application ideas can be found in their lacking ability to perform analogical reasoning. In the context of technological competence leveraging, analogical transfer is a prerequisite for recognizing a given technology used in a specific domain as a solution to similar problems in other domains. Research has shown that analogical transfer is difficult to achieve (e.g. Novick, 1988; Gentner and Markman, 1997; Chen, 2002; Gentner et al., 2004). For example, in a series of experiments Holyoak and Koh (1987) were able to show that only about 30% of subjects generated a solution based on analogical transfer prior to receiving an explicit hint to do so. Even in the case of problems within the same domain, such as geometry, anecdotal reports suggest that students seldom even notice analogies between problems presented in different chapters of their textbook (Holyoak and Koh, 1987). Especially novices – that is, individuals who are not used to performing such tasks – face difficulties with analogical transfer.

On the other hand, it is well known that inducing an explicit schema facilitates analogical transfer (Gick and Holyoak, 1983; Holyoak and Koh, 1987). In order to enable users to induce such a general schema in technological competence leveraging processes, the technology in question should not be presented on the basis of its features, which are basically irrelevant with regard to alternative applications (Arora and Gambardella, 1994; Arora et al., 2001). Instead, it is important to enable (potential) users to understand a technology's key benefits and thus its problem-solving capabilities. Knowing the types of problems that can be solved with a technology and its benefits (and thus being equipped with a schema), users will be more likely to discover areas where similar market needs/user problems arise and where the technology could serve as a valid solution to those problems. Providing only solution-based descriptions of a technology or publishing patent letters actually reduces the effectiveness of such search approaches by leaving it up to the user to extract a schema (i.e. use benefits derived from features of the technology), meaning that analogical transfer (i.e. the identification of viable markets for the technology) is impeded or at least made unnecessarily difficult.

A novel approach: Integrating user communities into technological competence leveraging

As discussed above, the major shortcomings of existing approaches to technological competence leveraging are the unsolved problem of 'local search behavior' and the frequent use of 'solution-based problem specifications'. Thus, new methodological approaches should address these specific barriers to the identification of novel applications to technologies and provide substantial support in overcoming them. In this paper, we propose a user community-based search approach as a possible solution (at least under specific conditions). In a nutshell, we suggest that technology-driven organizations should address the creativity inherent in communities of current and potential users when trying to leverage technological competences.

The role of users in technological competence leveraging

Drawing on external stakeholders to enhance innovation capabilities is a strategy which has seen more and more attention among researchers and practitioners alike (e.g. Agerfalk and Fitzgerald, 2008; Fleming and Waguespack, 2007; Jeppesen and Frederiksen, 2006; Nambisan and Sawhney, 2007; Pisano and Verganti, 2008). There is a broad stream of literature emphasizing users as a particularly valuable source of innovative thoughts, ideas or concepts to support new product development (Baldwin et al., 2006; Franke et al., 2006; Herstatt and von Hippel, 1992; Hienerth, 2006; Jeppesen and Frederiksen, 2006; Lettl et al., 2006; Lüthje et al., 2005; Morrison et al., 2000; Urban and von Hippel, 1988; von Hippel, 1988). It is also known that the user's perspective plays a central role in the process of leveraging technological solutions (Henkel and Jung, 2010; Souder, 1989). Recent research in the context of user-driven innovation clearly indicates that users are able to discover uses and usage situations for a given product or technological solutions not intended by and thus unknown to the original manufacturer of the product or the inventor of the technology (e.g. DeMonaco et al., 2006). Lead users (i.e. those who face an urgent need earlier than the bulk of the market) in particular seem to be a promising source of application ideas for existing technologies in terms of the number of ideas generated, as some empirical evidence shows (Henkel and Jung, 2010).[4]

The reasons for this strong focus on users as a source of innovation are manifold:

(1) Users have *use experience*. By definition, they know the product or the technology from a use perspective and therefore possess specific know-how about the benefits it delivers, its major flaws, and the types of problems it solves (DeMonaco et al., 2006; von Hippel and

[4] However, as lead users are by definition far ahead of the general market in terms of needs, the commercial potential of their ideas might be limited *in the short run* because of the relatively high innovativeness of application ideas and the resulting longer development time for the final product. Focusing on lead users only in the context of technological competence leveraging might prevent organizations from discovering market opportunities that can be exploited readily without requiring adaptations to the technology, which significantly reduces development time.

Katz, 2002; von Hippel, 2005). In many cases, it is the user rather than the manufacturer who knows best how and in which contexts a given technology or product delivers benefits (von Hippel and Katz, 2002; von Hippel, 2005). This aspect can be illustrated by the phenomenon of off-label drug use. Pfizer, for example, could not have anticipated the virility-enhancing effect of its bestselling drug Viagra without talking to its 'users'. Originally developed as a way to treat hypertension and angina pectoris, Viagra turned out to induce marked penile erections in the course of initial clinical trials. If participants had not reported their use of Viagra as an aphrodisiac, Pfizer might have never had the idea to market it as a drug for erectile dysfunction (DeMonaco et al., 2006). Thus, users might be an important source for revealing the true benefits of a technology and for generating a problem-based search specification, which is needed in the next phase of technological competence leveraging processes. In contrast, solution-based search specifications may ask too much of the (average) user by requiring him/her to identify the key benefits of a solution and thereby inhibiting analogical transfer.

(2) Users *think outside of the box.* Compared to the technology-owning company as well as its institutional stakeholders (such as suppliers or competitors), potential users are generally less bound by pre-existing expertise and know-how regarding features and assumptions about the technical applicability of a technology (Pötz and Prügl, 2010; von Hippel, 1994). Instead – especially if provided with a problem-based search specification – they regard the technology as an instrument capable of solving a specific kind of problem. Equipped with such a schema (Holyoak and Koh, 1987), potential users are enabled to recognize or remember situations in which they face(d) similar problems, even if they arise in a completely different domain (Duncker, 1945; Pötz and Prügl, 2010; von Hippel, 1994). As a result, they are able to come up with radically new application ideas, thus helping the company/inventor to overcome local search bias (see Lilien et al., 2002; Schreier and Poetz, 2010).

(3) Users are likely to provide a highly *valid evaluation of the commercial attractiveness* of the applications identified (Ho and Chen, 2007). The value of a given application is determined by the market (Priem and Butler, 2001). It is the individual future user who decides to make use of a certain technology in order to resolve an existing problem. This decision is influenced by several aspects: First, there must be a problem that is important enough to prompt the user to look for and adopt a solution. Second, the costs related to adopting the solution must be lower than the benefits an individual derives from solving the problem. Third, substituting solutions (if there are any) must have a lower benefit/cost ratio than the solution based on the technology in question. Successfully leveraging technological competences involves collecting and comparing this information for every potential application in order to identify the most attractive ones from a commercial perspective. Potential users generally possess this kind of information, and therefore they might play an important role in evaluating the applications identified (Ho and Chen, 2007).

What are user communities and why are they helpful?

In order to receive benefit from the unique perspective of users in technological competence leveraging projects, organizations first have to find those users who are capable of providing valuable support. This is a challenging task, as not every potential user has the creativity, skills and abilities necessary to contribute highly novel solutions to innovation problems (Kogut and Metiu, 2001; Lakhani and von Hippel, 2003). It is well known that finding actors with rare and very specific expertise (e.g. stemming from an appropriate analogous field and being capable of contributing a viable solution) within large, poorly mapped search spaces is a problem frequently encountered by innovation researchers and managers (e.g. Olson and Bakke, 2001; Lilien et al., 2002; von Hippel, Franke and Prügl, 2009). One possible way of effectively and efficiently identifying those users who are most likely to provide valuable input is to make use of user communities, an emerging phenomenon fostered by advances in information and communication technologies.

User communities can be characterized as informal social networks in which individuals exchange technological and/or market-based information, knowledge and innovative thoughts as well as artifacts related to a certain product or technology (von Hippel, 1994 and 2007). For members, the purpose of a user community is to generate new knowledge, to post and solve particular problems, and to develop innovative ideas or new technologies for existing or new applications (von Hippel, 2005; Franke and Shah, 2003; Harhoff et al. 2003; von Krogh et al. 2003; Jeppesen and Frederiksen 2006; von Krogh and von Hippel 2006; Lakhani et al. 2007). Besides their individual problem-solving capabilities, members of user communities usually have another type of highly important information: If they participate actively in the community activities and frequently interact with others, they are likely to know the members of the core community as well as the specific competences of many members. For example, core members are usually responsible for most of the communication and development contributions in these communities (Kogut and Metiu, 2001; Lakhani and von Hippel, 2003). Thus, organizations striving to find highly creative users in order to integrate them into technological competence leveraging activities might benefit from entering a community of potential users and systematically searching for the most active contributors (the core members), lead-users or other individuals with very specific sought-after attributes. Two search strategies aiming to identify persons with specific attributes, e.g. know-how about a specific problem that could be solved by a given technology, are pyramiding and broadcasting (Poetz and Prügl, 2010; von Hippel, Franke and Prügl, 2009) The common premise of these search approaches is based on Hayek's (1945) central insight that knowledge is unequally and widely distributed among individuals and the main challenge in society is to find ways to access and build upon this knowledge (Lakhani et al., 2007).

Pyramiding is a search process based on the idea that people with a strong interest in a given attribute or quality, for example a particular type of expertise, will tend to know of people who *know more about and/or have more of that attribute* than they themselves do (von Hippel, Thomke and Sonnack, 1999). The pyramiding process is quite simple in concept: One simply asks an individual to identify one or more others who she thinks has a higher level of the attribute sought – or better information regarding who such people might be. The researcher then poses the same question to the persons so identified and continues the process until individuals with the desired high levels of the attribute (i.e. the 'top of the pyramid') have been identified (von Hippel, Franke and Prügl, 2009). In contrast, broadcast searches involve posting a certain question or problem within a user community. By collecting, reviewing and analyzing the responses submitted, the most interesting respondents can be identified and then integrated into the technological competence leveraging project (Lakhani et al., 2007).

However, user communities are not only helpful tools to identify 'expert users'. Another very important aspect of user communities is the 'power of the crowd'. Members of user communities usually interact with each other when working on ideas or solutions to a given problem: They pool their competences, inspire and support each other, and provide feedback on other users' preliminary solutions (Franke et al., 2009; Jeppesen and Molin, 2003; Prügl and Schreier, 2006). This joint effort of peers often results in solutions that are superior to those of individual problem solvers (Amabile and Gryskiewicz, 1987; Franke et al., 2009; Jeppesen and Molin, 2003; Prügl and Schreier, 2006; Raymond, 1999; Sethia, 1991). The quality of solutions to innovation-related problems has been shown to improve with the increased heterogeneity of community members in terms of professional, educational and social backgrounds (Franke and Shah, 2003; Harhoff et al,. 2003). Recent empirical research has shown that how *widely* an organization explores external knowledge has a strong influence on its performance in creating new ideas (e.g. Huston and Sakkab, 2006; Katila and Ahuja, 2002). Furthermore, the *distance* between the context of the organization facing an innovation-related problem and that of potential problem solvers seems to be an important driver for the generation of truly novel solutions in exploring external knowledge (e.g. Lakhani et al., 2007). Arguably, users primarily from *analogous domains* could contribute to finding new applications for existing technologies (a problem which is similar in structure to new product development) and thus help overcome local search bias in the course of technological competence leveraging activities (e.g. Franke and Poetz, 2008; Lilien et al., 2002; Rosenkopf and Nerkar, 2001; Stuart and Podolny, 1996). As the members of user communities usually have highly heterogeneous professional, educational and social backgrounds, user communities might provide an effective means of accessing know-how from many different and thus even far-analogous domains.

As argued above, user communities are likely to produce better ideas regarding new market opportunities for existing technologies than individual users. In addition, the power of the crowd might also be important in evaluating the commercial potential of different application ideas. User communities allow the collaborative filtering of ideas and opportunities (von

Hippel, 2005). This means that the periphery of users – the vast number of community members not involved in the generation of application ideas – serve as a kind of test market. A number of studies have emphasized the power of user communities in predicting the future market success of community-generated solutions and concepts (e.g. Dellarocas et al., 2007; Godes and Mayzlin, 2004; Lakhani et al., 2007).

Case study: Exploring user community-based search processes at RallyPoint, Inc.

The idea of integrating (communities of) current and potential users into the process of technological competence leveraging seems reasonable. As described above, users might provide substantial support in identifying and evaluating alternative applications for existing technologies. However, little is known about how to implement such a user community-based approach to technological competence leveraging and how effective such an approach might actually be. Moreover, no specific research projects have focused on or discussed the conditions affecting the success of user community-based approaches to technological competence leveraging.

In order to shed some light on these issues, a qualitative approach was chosen for this research, as qualitative methods allow complex issues – such as a community-based approach to technological competence leveraging – to be investigated in some depth (Yin, 2003) by building an understanding of the processes and dynamics within particular settings (Eisenhardt, 1989). More precisely, an exploratory case study was considered the appropriate research tool because the available theory was not sufficient generate predictions about design principles and the effect of user community-based searches for market opportunities.

Subject of investigation

RallyPoint is a startup founded by MIT students/alumni with the vision of delivering solutions that reliably enhance the safety and effectiveness of soldiers. The focal point of this case study was the Handwear Computer Input Device (HCID) technology developed by RallyPoint under a Small Business Innovative Research (SBIR) contract from the United States Army. RallyPoint constructed a working prototype of a sensor glove based on its HCID technology. This sensor-embedded glove is capable of recognizing 1) intuitive single-handed gesture commands and 2) direct 'hands-on-weapon' input actions, and relaying them to an interfaced electronic device such as a wearable computer, two-way radio, or robot control unit. Gesture commands are recognized by a suite of sensors that detect hand posture and orientation, and hands-on-weapon input actions are detected by thin, flexible force sensors strategically placed throughout the glove. These sensors and their supporting conduction network are fully integrated into the glove's fabric to maintain the look and feel of a conventional military glove (a demo video of the HCID technology is available at http://www.rallypoint.info/GloveDemo.mov).[5]

RallyPoint faced the problem of how to systematically identify additional markets for their existing technology outside the military field. The search for additional fields of application turned out to be a major challenge. RallyPoint brainstormed five application ideas and ultimately identified two user groups who might use the HCID glove: firefighters and police officers. Both have occupational needs similar to those of soldiers: e.g. they may need to communicate with team members using hand signals, or operate a radio while handling other devices such as a weapon, firehose or ax. Although the two user groups seemed to be commercially attractive because of their potential market sizes, the RallyPoint team was not satisfied, as they doubted that the company would be able to enter these markets successfully within a reasonable period of time. Firefighting and law enforcement are both government domains, and gaining access to those areas is a costly and time-consuming task which may additional require extensive lobbying. Based on these considerations, RallyPoint decided to expand their search activities in order to identify a wider spectrum and a larger number of additional fields of application.

In Spring 2006, one of the authors attended a talk given by one of RallyPoint's co-founders in which the latter discussed the RallyPoint story, demonstrated its glove prototype, and talked about their search for consumer applications. Afterwards, they found that there might be a synergistic match, and Forrest Liau (co-Founder and President of RallyPoint) and Tony Eng (co-Founder and Principal Software Engineer) agreed to participate in an exploratory case study in order to empirically explore the potential of a user community-based approach to finding and evaluating alternative fields of application to their HCID glove technology.

RallyPoint seemed to be a suitable specimen for a case study, as the company and its technology met some very important prerequisites. Thus, this case was selected for a number of reasons: (1) RallyPoint's founders had a pressing need to identify alternative applications for their technology. They had explored different approaches to technological competence leveraging prior to the research project, allowing the authors to compare the effectiveness of existing approaches to a user community-based one. (2) RallyPoint offered the advantage of

[5] *Important features of the HCID technology:* (1) provides choice operating position without the need for additional weapon attachments; (2) is lightweight; self-contained, and non-interfering; (3) recognizes hand-arm gestures for multipurpose input and directional referencing; and (4) can be a versatile electronics platform for a variety of possible devices (e.g. metal detector, lifesign sensor, etc.). *Major benefits of the HCID technology:* HCID enhances the functionality and usability of wearable soldier systems. Users can: (1) select the view mode of helmet-mounted displays without having to take their hands off a weapon or vehicle handgrip; (2) operate a small unmanned ground vehicle from a combat-ready posture; (3) enjoy hands-on-weapon input capabilities without being tethered to their weapons; and (4) input commands into their computers using intuitive hand-arm gestures.

already having a working prototype of the HCID glove, which made it possible to build on an existing community of current users in order to find out about the technology's benefits from a use perspective. (3) RallyPoint agreed to contribute to the case study by flying to Vienna to meet with the research team, and providing the research team with internal, secondary data such as information about current users, a list of existing application ideas, and other resources.

Data gathering

Data was collected between 2005 and 2007. The authors employed a two-step qualitative approach in this research effort:

Step 1 – Generating a methodological framework for employing a user community-based approach to technological competence leveraging

Following the recommendations of Yin (2003), Dubois and Gadde (2002), and Eisenhardt (1989), data for this investigation was collected from a variety of sources, including primary (several interviews and a focus group) as well as secondary sources (e.g. an extensive literature review of research publications dealing with technology-push innovation strategies, technological competence leveraging and user innovation; company documents from leading high-tech firms as well as technology transfer offices located at universities worldwide; press articles and government reports). The authors conducted semi-structured interviews with experts from university technology transfer offices and company experts responsible for innovation and technological development as well as a focus group exercise in order to generate different perspectives on technology commercialization. These measures enabled the authors to understand why and under what conditions the commercialization efforts of existing technologies were successful (or not).

The interviews commenced with a warm-up stage in which marketers discussed their roles and responsibilities in detail. The discussion then focused on exploring the experts' understanding of technological competence leveraging and commercialization in the high-tech category. Expert interviews averaged about 40 minutes in length. In addition to the interviews, institutional and company documents were also analyzed. Organization-related documents included 'An Inventor's Guide to Technology Transfer at the Massachusetts Institute of Technology', internal documents describing commercialization success factors, reports on longitudinal commercialization patterns, and market research on tech transfer patterns and trends, to name but a few examples. The project concentrated on all aspects of technology commercialization and investigated more than 20 organizations/companies in semi-structured interviews.[6] The subsequent focus group consisted of eighteen participants.

[6] Including Austria Wirtschaftsservice GmbH (AWS), Babson College, CNSystems Medizintechnik AG, Columbia University, Dallmann & Juranek Rechtsanwälte GmbH, Hewlett Packard, Massachusetts Institute of Technology, Medical University of Graz, OMV AG, Rochester Institute of Technology, Siemens AG Österreich, Smartfood Holding GmbH, Stanford University, The Austrian Federal Economic Chamber (WKO), University

The researchers developed an outline of the topics to be covered, with suggested questions that were designed to keep the conversation flowing. This format allowed the researcher some freedom to follow up on insightful responses (Steinart, 1996).

Step 2 – Gathering data from the case

During the exploratory case study, the authors frequently interacted with Forrest Liau and Tony Eng. Data was again collected by using both primary and secondary sources of information. In order to explore design principles for a user community-based approach to technological competence leveraging, to evaluate its effectiveness and to learn about its prospects and challenges, the authors conducted several in-depth interviews with the representatives from RallyPoint at different points in the research project. At the beginning of the research project, they provided first-hand information on the size, age and governance structure of their organization as well as relevant information about the technology to be leveraged. At the end of the innovation project, RallyPoint's founders recapitulated the research project and commented extensively on its processes and outcomes. The authors were also able to draw on many other forms of data, such as internal project reports, presentations and minutes of meetings which summarized the process and execution of the project. This triangulation process based on additional secondary data should help to reduce biases due to recall inaccuracy (Amaratunga and Baldry, 2001; Maxwell, 1996; Podsakoff et. al., 2003).

Data analysis

For data coding purposes, all documents and interview transcripts were numbered consecutively and coded using six different aspects related to the exploration of specific design principles and effectiveness measures for a user community-based approach to technological competence leveraging:[7] (1) level of novelty of identified use benefits of the technology (coded as 1 = use benefit identified through user community already known to company/inventor, 2 = use benefit identified through user community previously unknown to company/inventor); (2) description of viable field of application (coded consecutively from 1 to n); (3) type of search process used in order to identify a specific viable field of application (1 = pyramiding, 2 = broadcasting, 3 = combination of pyramiding and broadcasting); (4) level of novelty of identified field of application (coded as 1 = field of application identified through user community already known to company/inventor, 2 = field of application identified through user community previously unknown to company/inventor); (5) 'technical feasibility'[8] of identified field of application (1= field of application identified through user

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of California Berkeley, University of Salzburg, University of Veterinary Medicine Vienna, Vienna University of Economics and Business Administration, and Vienna University of Technology.

[7] (1) The exploration/identification of design principles (research question 1) emphasizes the generation of multiple viable market opportunities rather than their evaluation. (2) The exploration of effectiveness (research question 2) is designed to obtain measures indicating whether and to what extent the approach is able to overcome 'local search bias'.

[8] ‚Technical feasability' means that the existing technical solution/or a slightly modified solution will work under the specific requirements of the field of application. E.g. application field ‚underwater welding' would not

community considered technically feasible by company/inventor, 2 = field of application identified through user community considered technically *in*feasible by company/inventor); (6) distance between the original field of application (military use) and the identified field of application (coded with 1 = field of application identified through user community found in a near-analogous domain or 2 = field of application identified through user community found in a far-analogous domain).

Variables (1) to (5) were coded independently by two geographically dislocated coders based on a three-step process (Krippendorff 2004, Hayes and Krippendorff 2007): (1) Training, (2) Individual Coding, (3) Discussion and optional modification. Values for intercoder reliability for these variables lie at a very satisfactory level (Cohen's Kappa > .800 throughout all variables). In order to provide a reliable estimate of whether a certain application is near-analogous or far-analogous (variable 6), we asked two independent experts from the field of innovation management to assess all applications identified with the user community approach to technological competence leveraging. The experts were asked to rate each field of application on a four-point Likert scale (1 = application is very similar to the target market application [HCID as an instrument to control the radio while keeping one's hands on the rifle], 4 = application is not at all similar to the target market application). Applications which scored less than 2.5 on average were interpreted as near-analogous fields. Those with higher average scores were regarded as far-analogous applications. Interrater reliability among the two experts concerning the assessment of the 32 applications identified resulted in a Cohen's Kappa of .430 which indicates a fair level of agreement among raters (see Landis and Koch, 1977).

Findings

Step-by-step guidance for a user community-based search approach to technological competence leveraging[9]

One of the major outcomes of this exploratory research is the deduction of a detailed pattern describing how an effective user community-based search approach to technological competence leveraging might look. The RallyPoint case provides some empirical evidence for the supportive function of communities of current and potential users. Four distinctive steps or phases in a user community-based approach were identified in this research project. However, in this paper the first two steps are emphasized heavily, as the integration of user communities in the identification of an abstract problem description and in the systematic

be feasible if the HCID-technology does not work under water or if costs of modification would be disproportional.

[9] In the practical realm, the resulting user-driven search approach to technological competence leveraging has become known as the 'ISAA method'. ISAA can be interpreted as an acronym for Iterative Search for Alternative Applications and also reflects the four steps involved (Identify, Search Analyze, Assemble).

search for additional applications may have the strongest impact on overcoming the shortcomings of traditional approaches to technological competence leveraging.

Step 1: Identify a problem-based search specification

The first step derived from our study involves an in-depth exploration of the technology. The goal is to fully understand it from a benefits perspective, that is, to identify its unique benefit dimensions. One starting point here is to analyze the situation in which the technology is used in the originally intended application (where possible). Employing this approach does not necessarily require the search team to know all the functional details of how the underlying technology works. What really matters is to get an idea of how the technology creates value for its potential users. In this step, the following questions were identified as central, and discussion within the search team revolved around these issues: What benefit can a (potential) user draw from the technology? What are the most important features of the technology/product and why are they important? Which needs does the technology potentially fulfill? Having understood how current users benefit from the technology, the search team then translated those insights into an abstract problem-based search definition (i.e. an abstract schema).

Based on different sources of information (e.g. a working prototype of the HCID, a promotional video showing a soldier using the HCID on a fictitious scouting mission, company-internal documents and presentations), the RallyPoint search team first tried to gain a basic understanding of the technological solution. Subsequently, 17 current and potential users of the HCID technology who had either already used the prototype or seen the above-mentioned demo video were interviewed. In the team's efforts to identify suitable interviewees, the advantage of drawing on user communities instead of individual users became obvious. The search team used personal ties between current and potential users in order to find additional interviewees. Starting with the first user, each interviewee was asked to name other people who were familiar with the HCID or able to understand the benefits it might deliver in order to identify additional respondents who could contribute to generating a problem-based search specification. The 17 interviewees were asked to express the potential benefits of the technology from their perspective as users and in their own language. Drawing on statements such as "*...the sensor-embedded glove enables me to control devices like my radio without having my hands go off the rifle...*", "*...I can control my devices without having to speak, which is of advantage on scouting missions or throughout gunfire...*", and "*...even minimal finger and hand gestures are noticed by the HCID glove and translated into digital inputs, which is of advantage if you are in a dugout…*" three main benefits of the HCID technology were identified. These benefits were multitasking (doing several different things like holding the rifle and controlling the headset at the same time), noise independence (ability to control devices without speech, which is important in very loud surroundings or when noise has to be avoided), and minimal space requirements (ability to control devices with only the smallest finger movements when space is limited – as in a dugout). Interestingly, RallyPoint had not previously perceived the importance of the latter two benefits of their technology.

Step 2: Search systematically for alternative application areas by interlocking broadcast and pyramiding search methods

In this phase of the user community-based approach to technological competence leveraging, the main objective was to identify as many concrete applications for the existing technology as possible. However, instead of looking directly for other applications (based on a technological view), in our case study this was done by systematically searching for people with high levels of knowledge or experience regarding problems linked to the benefits defined in the first step. In order to identify a wide range of different possible applications, it seems necessary to introduce the technology's use benefits (the problem-based search specification), formulated as an abstract schema, to a large number of people from as many different fields and professions as possible. One imperative was to ensure that the problem-based description of the technology was presented to the interviewees in an easy-to-understand format, accompanied by figures or videos showing the technology in use when solving a specific problem (if possible). The interviewees were then asked (1) whether they were familiar with situations in their professional lives in which they regularly faced those problems or where those problems played a central role, (2) whether those situations really mattered to them (level of eagerness for a solution), (3) whether they thought a solution to this problem would also be beneficial to others facing the same problem, and (4) whether they knew other persons who faced a similar or somehow related problem and could therefore benefit from a solution.

As this is one of the most critical activities within the proposed framework, a great deal of cognitive effort has to go into the preparation of and the actual search for adequate interviewees. In the RallyPoint case, two different systematic approaches had been used to search for people with certain characteristics (i.e. facing a specific type of problem in their professional lives): pyramiding and broadcasting. Based on a wider, more abstract and problem-based search specification (e.g. 'Do you know of use situations where you would need a third hand?' for the major benefit of the technology's multitasking capability), the search process for markets where these benefits are relevant was started. The RallyPoint search team (supported by 14 specifically trained undergraduate students) conducted 152 pyramiding search interviews and broadcast similar questions (postings of the search specification) in 37 online communities. As a result of this broad search process, 32 valid applications, ranging from motorcycling (control of the navigation system) to underwater filming (holding a heavy camera with two hands and controlling the buoyancy vest at the same time) and rehabilitation after a stroke (sensor-embedded glove as an instrument which gives feedback on the success of movement exercises) were derived.

Interestingly, pyramiding and broadcasting search turned out to enrich each other substantially. The observations collected during the research project indicate that combining the pyramiding and broadcasting search methods in order to identify application ideas is superior to employing those methods independently of each other. Nearly 72% of the applications were identified using a combination of pyramiding and broadcasting searches. Individual users with low expertise, for example, often referred to user communities instead of specific persons. In turn, the members of those user communities were the starting points for a continuing pyramiding search. Figure 1 illustrates a typical search process leading to a viable application idea.

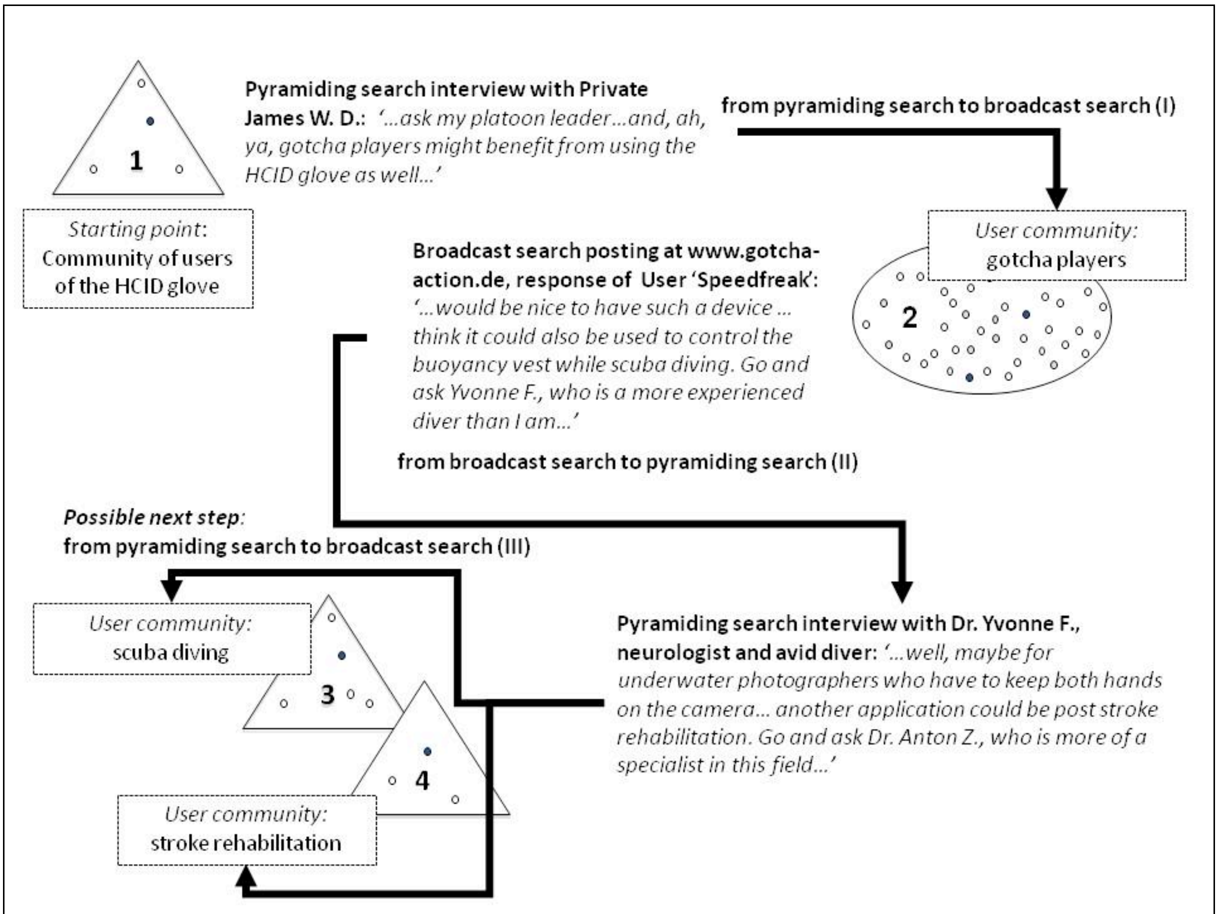

Figure 1: Illustration of a typical search process

In addition, drawing on user communities and accessing their members' social networks to find new interviewees instead of interviewing randomly chosen individual users seemed to propel the search for valid applications. On average, the project team had to contact four community members in order to identify a viable alternative application. In other words, almost 25 % of all interviews led to valuable results. Thus, the search approach taken can be regarded as fairly efficient. This result is consistent with findings from other research. Recently, von Hippel et al. (2008) showed empirically in a number of controlled experiments that the pyramiding search approach is a highly efficient method for the identification of actors with rare specific characteristics or expertise (e.g. facing a specific use problem) within large, poorly mapped search spaces under various conditions.

Step 3: Analyze potential application areas through users

Once the potential fields of application have been identified, the next step is to evaluate their commercial attractiveness. Due to limited resources, it is necessary to identify the most promising applications in order to decide which markets to enter first. The exploratory case study revealed a two-stage process in the analysis of different fields of application. The first stage of this analysis is intended to support the searching entity (e.g. a start-up team) in quickly rejecting those applications that do not satisfy the basic criteria for successful commercialization of the technology. In this stage, all potential fields of application are rated with respect to their fit with the company's strategy as well as the number of use benefits relevant in the particular application and their relative importance. Generally speaking, the more benefits are highly relevant within a certain field of application and the better that field corresponds to the strategic alignment of the company, the higher the potential success of the ensuing commercialization effort will be.

Step 4: Assemble an actionable commercialization strategy

The last step within the framework dealt with assembling an actionable commercialization strategy. Although it should be clear from the previous steps which new markets are to be tackled first, the important question of *how to* commercialize the technology is still left unanswered. Thus, in this fourth step the RallyPoint team dedicated resources to developing what might be called 'commercialization proposals'. For each field of application, the team drew up a brief report describing (1) the concrete problem which can be solved by the given technology in the specific field of application, (2) the market potential and future growth rates, (3) substitutes and products from competitors (where applicable), (4) potential user companies or distributors, as well as (5) strategic options regarding the commercialization mode (ranging from creating a new company to commercialize the technology to licensing the technology to established players or start-ups).

Effectiveness of the user community-based approach to technological competence leveraging

The primary intention of this paper is to introduce the idea of user integration into the field of technological competence leveraging. The authors argue that involving user communities in the process of systematically searching for alternative applications for existing technologies is likely to enhance the success of such activities by overcoming well-known shortcomings of traditional approaches (such as 'local search bias') to technological competence leveraging. Although this research project was not designed to compare the effectiveness of traditional approaches and the user community-based approach suggested in this paper, the authors also wish to report on the results of the search for alternative applications for the HCID glove. The outcomes of the exploratory case study provide some empirical evidence for the effectiveness of the approach presented above.

The first very important result of the user community-based search approach was the identification of two new benefits of the HCID technology. In contrast to multitasking, the benefits of noise independence (ability to control devices without speech, which is important in very loud surroundings or when noise has to be avoided) and minimal space requirements (ability to control devices with only the smallest finger movements when space is limited, as in a dugout) had not been recognized or regarded as being important by the inventors. However, the latter two 'new' benefits turned out to be highly important in the next step (searching for applications). In 12 out of 32 applications identified (e.g. in the case of virtual stroke rehabilitation therapies), the benefits of noise independence and minimal space requirements were far more important than multitasking. Thus, only searching with multitasking in mind might have prevented the RallyPoint search team from finding such a large number of viable business opportunities.

Another important aspect pointing to the effectiveness of the user community-based approach to technological competence leveraging is the absolute number of identified applications: As mentioned above, 32 applications were identified, which is rather high compared to the number of ideas generated by RallyPoint alone. A deeper analysis of these 32 concrete applications shows that 27 of the 32 applications identified were new areas of application previously unknown to RallyPoint. Additionally, all but one of the application fields identified were assessed as viable business opportunities from the company's point of view. The only exception was 'sign language'. Due to the current limitations of the technology itself, using the HCID glove as a device to translate sign language into digital signals seemed possible only with extensive additional research and development effort (see table 2).

Total number of valid applications identified	*Number of previously unknown applications (in %)*	*Number of 'technically viable' applications (in %)*	*Number of 'far-distant' applications (in %)*
32	27 (84.4)	31 (96.9)	22 (68.8)

Table 1: Number and key characteristics of applications identified in the user community-based search process

Another striking result is the proportion of far-distant applications among the potential uses identified. As shown in table 1, a large proportion (68.8%) of the applications were considered to belong to far-distant areas in relation to the target application in the military field.[10] This finding highlights the fact that the user community-based search process enabled the exploration of far-analogous areas previously unknown to the company – thus helping to overcome its local search bias.

There is also some evidence on the effectiveness of the community-based indicators ‘benefit relevance’ and ‘strategic fit’ to assess the commercial attractiveness of the applications identified. RallyPoint’s representatives conducted an independent market analysis of the applications resulting from the user community-based search and decided to follow their suggestions. Thus, ‘benefit relevance’ and ‘strategic fit’ as measured on the basis of user inputs seem to be highliy valid indicators for deciding which markets to enter with an existing technology.

Conclusions from the case study

The basic objective of this paper is to complement the traditional, usually company-centered technological competence leveraging process with a more externally oriented perspective. The authors propose a user community-based approach to the processes of systematically searching and evaluating new application ideas for an existing technology. In this context, it is argued that integrating current and potential users could provide substantial support in the search for new business opportunities for a certain technology. In line with the research questions presented above, the primary objectives of this paper were 1) to explore whether and how user communities can contribute to technological competence leveraging processes, and 2) to examine how effective such a community-based approach is in identifying new application ideas by overcoming local search bias.

The findings and conclusions which can be drawn from the case study yield significant insights into the questions raised above. It appears that cooperating with current and potential technology users in technological competence leveraging can indeed be a promising strategy. Compared to the five pre-existing application ideas generated within the company, the number of potential markets identified with the user community-based search approach was five times higher. The larger number of applications identified has to be attributed partly to the fact that user communities helped in discovering two additional benefits of the HCID glove (as identified in interviews with current users), which in turn enlarged the technology’s scope of application to completely new types of problems. These figures provide an initial indication of the potential strength of the user community-based search approach. Another measure pointing to the validity of this approach – as compared to internal brainstorming – is

[10] See method section for details.

the rather high proportion of far-distant application areas. Nearly 69% of the applications identified can be regarded as far-analogous in the sense that those areas share structurally similar features with the target market application (as opposed to mere surface similarity). Thus, the user community-based approach seems to provide ample support in overcoming local search behavior. The authors attribute this result to the fact that pyramiding as well as broadcasting (as described in the literature review section) are valuable instruments to cross the company's boundaries (von Hippel, Thomke and Sonnack, 1999; Lilien et al., 2002; Hienerth, Poetz and von Hippel, 2007). Recently, Poetz and Prügl (2010) analyzed 1,147 interviews conducted in the course of pyramiding search processes in eight lead user studies and were able to show that pyramiding *is indeed an apt means of systematically crossing domain-specific boundaries*: More than one third of those interviewees who provided a valid referral in their interview performed the creative task of referring into one or more analogous domains *previously unknown* to the searching organization. Even the early work of Souder (1989) stated that successful technology push depends on broadcasting knowledge of the technology throughout user communities in order to "maximize the chances of a 'collision' between the technology and its potential uses" (p. 21).

Furthermore, communities of users also contributed by enabling the formulation of a problem-based search specification, thus making it easier to interact with potential users from different, even far-analogous fields. In summary, the findings provide initial empirical insights which show that companies should not only adopt internally oriented approaches when trying to identify viable business opportunities for their technologies. Instead, it appears useful to make use of the intelligence of the crowd outside the company.

Discussion and further research

One limitation of the research approach taken is its investigation of a single case only. This exploratory case study approach provided the authors with opportunities to develop an in-depth understanding of the process of user community-based searches for the purpose of technological competence leveraging, but it clearly limits the generalizability of the study's findings. In particular, it is difficult to generalize findings regarding the effectiveness of the process to different types of technological competences as well as other organizational contexts. Nevertheless the process itself (the four distinct phases discovered, see page 17) seems to be applicable to different settings and thus should have a rather high generalizability. Examining more cases would serve to enhance our understanding of the contextual contingency of the effectiveness of the user community-based approach explored in this article.

Given that limitation, one promising contingency factor subject to further investigation could be the "nature" or scope of the technology. It seems reasonable that a so-called 'general purpose technology'[11] that unfolds through a sequence of innovations which take many shapes as distinct embodiments of the basic technology (Bresnahan and Trajtenberg, 1995; Rosenberg and Trajtenberg, 2004) will *by definition* have broader applicability compared to more specific technologies or technological solutions. Thus, the scope of the technology could be considered a moderating variable with regard to the effectiveness of the user-based approach that should be integrated into future research efforts.

Another interesting observation arising from the RallyPoint case is the fact that all of the applications identified for the HCID technology are based on the idea of embedding the sensor technology into a glove. Although RallyPoint's technological competence in using highly sensitive sensors to translate human movements into digital inputs is theoretically not bound to finger and hand gestures, the users interviewed did not come up with the idea of adapting the form of the artifact (the glove) which houses the technology. It would have been possible, for example, to propose a full body suit equipped with sensors, which may have enlarged the number of possible applications. The authors assume that adhering to the artifact of a glove was largely triggered by the presentation of the working prototype instead of the underlying technology itself (i.e. the sensors). Even if users are able to transfer the problem-solving potential of a certain technology from one use context to another, they obviously encounter difficulties in anticipating possible adaptations and changes to the technology. This observation is in line with the literature on distributed problem solving. With regard to the role of artifacts in distributed problem-solving processes, it has been shown that the existence of an artifact reduces the number of trajectories and solution paths identified and followed (e.g. Carlile, 2002). This effect also appears to limit the solution space in the search for alternative application ideas. Thus, companies which employ a user-centered approach to leveraging technological competence should be aware of the importance of the form in which the technology is presented (Arora et al., 2001).

The cognitive fixation of current and potential users on the actual artifact (Duncker, 1945) in which the technology is incorporated (e.g. a glove, as mentioned above) raises another important and related question: If users stick to the actual artifact – the product containing the technology – in their analogical reasoning, would they still be able to come up with application ideas if such an artifact were missing? Carlile (2002) emphasizes the importance of artifacts in problem-solving processes. Although they limit the solution space, artifacts do provide valuable starting points which foster efficient problem-solving processes. Thus, if such artifacts or starting points are missing at all, this could constrain effective problem solving (Akin, 1978; Franke et al., 2009; Van Lehn, 1998). The problems of university-owned technology transfer offices in commercializing 'generic technologies' which have often not yet been transformed into a marketable product might be an indicator of the importance of

[11] Examples include the steam engine, railroad, electricity, electronics, the automobile, the computer, and the Internet.

artifacts as prototypes or existing products in technological competence leveraging (Wadhwa, 2007). Based on the RallyPoint case alone, the authors cannot claim to know whether the stage of development of a certain technology (concept vs. prototype or product ready for commercial use; e.g. Thursby, 2001) influences the users' ability to recognize its problem-solving capabilities and to identify problems in their professional or private lives that might be solved by the technology. However, it would be worth investigating the role of different development stages of technologies and the necessity of existing artifacts in the course of technological competence leveraging activities.

Another related aspect which may affect the success of user community-based search approaches to technological competence leveraging and is worth investigating is the role of current users in the first step (generation of a problem-based search specification). As argued above, users are helpful in revealing the full range of benefits derivable from a technology as well as its problem-solving potential because of their use experience (Lilien et al., 2002; von Hippel, 2005). In the RallyPoint case, current users contributed heavily to the result by pointing to two use benefits which had not been recognized by the inventors. Thus, it could prove problematic to come up with a problem-based search specification in cases where there are no current users. In particular, very new technologies that have not been used prior to the search for alternative applications would have to be explained to potential users instead of being analyzed by talking to current users. The effectiveness of this alternative procedure remains questionable.

The RallyPoint case also points to another area which warrants further research, namely the question of how to optimize the structure of the search process. As shown in the findings section, the separate use of either broadcasting or pyramiding only led to approximately 28% of the application ideas identified. The remaining 72% of the ideas were found by combining pyramiding and broadcasting searches in different ways. Future research should look into the optimal search configuration, compare and evaluate different types of search processes, and/or try to identify different patterns of combining the pyramiding and broadcasting search approaches in different contexts.

In summary, the authors suggest that user communities can be highly valuable to organizations trying to leverage their technological competences. Drawing on the data from the RallyPoint case, a framework was generated in order to provide operational support in employing such a user community-based search to identify alternative applications for existing technologies. The results indicate that the approach is effective in overcoming local search bias. However, the findings of this project are somewhat bound to the specific case investigated. Further research (e.g. comparative case studies) is needed in order to draw conclusions on the generalizability of the effectiveness of the approach presented.

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