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INNOVATION AS A COMMUNITY-SPANNING PROCESS: STRATEGIES TO HANDLE PATH DEPENDENCY

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Abstract

In this paper, we further develop and apply the notions of path creation and path dependency during technological innovation processes. The process of technological innovation is portrayed as an activity of spanning boundaries between and across communities of practitioners. Communities of practice are characterised by shared beliefs, evaluation routines and artefacts. These beliefs, routines and artefacts create powerful path-dependencies that inhibit path-breaking innovations. Based on exploratory empirical research, a model on handling path-dependency during the creation of technological innovations is proposed.

Innovation as a process spanning community boundaries: setting the stage

Research into the management of technology and innovation has highlighted the many pitfalls and problems that are usually encountered during the innovation journey. At different levels of attention and analysis, early work in the field (e.g. Allen, 1963&1966& 1969&1977; Myers and Marquis, 1965; Pelz and Andrews, 1967 to name just a few) has pointed to the importance of problem-framing and problem-solving activities to accomplish the innovation task at hand. In essence, this rich and diverse stream of research has pointed to the central role of handling (and from a performance point of view, reducing) uncertainty during the various phases of the innovation process. Information and information exchange were considered and shown to be critical elements in this endeavour. An excellent (summary) reflection on the various aspects and focal points of this research programme can be found in a 1995 article that was written by Shona Brown and Kathleen Eisenhardt.

Going through this research programme in greater detail, however, reveals that at various stages, the innovation process benefits enormously from boundary-spanning information exchanges and insights. Scholars like Thomas Allen and Michael Tushman have pointed to the important roles played by gatekeepers or boundary-spanners during innovation processes. Not only does this boundary-spanning activity play an important role during the implementation and problem-solving phases of the innovation process, but, as these and other authors suggest and demonstrate, the problem-framing or gestation phases of the innovation process may benefit from these

boundary-spanning interactions as well. It is not the aim of this short paper to review all of the findings and evidence at hand to support this boundary-spanning notion. However, we dare state that, following the French saying that *"du choc des idées jaillit l'esprit"* the concept of boundary-spanning has received widespread attention and support as one of the key phenomena that occur or should occur during any innovation effort.

Using the concept of boundary-spanning as a starting point for the research reported in this paper, though, immediately reveals the problematic nature of the concept as well. Throughout the innovation literature, boundary-spanning activities have been most often investigated at the level of the innovation *project*. At that specific level of analysis, boundary-spanning is important and problematic at the same time, because it points to the necessity to confront and integrate different "functions" (e.g. marketing, R&D, engineering) or "disciplines" (e.g. mechanical engineering, electrical engineering, chemical engineering) or "grammars" (e.g. algorithmic or symbolic reasoning in the area of artificial intelligence versus adaptive learning approaches in the area of neural networks) within and across organisations during the development of new technological knowledge and/or artefacts. As described and argued by scholars like Constant (1980), Nelson and Winter (1982), Garud and Rappa (1994), each of those distinct disciplines, functions or grammars are represented by communities of individuals who create and find their rallying point around a complex interaction of beliefs, evaluation routines and artefacts.

This complex interaction is at the origin of the genesis of non-trivial path-dependencies that in turn inhibit or impede upon this boundary-spanning activity. In sum, innovation requires spanning boundaries across communities, though at the same time, communities create important impedance effects that prevent and imperil this boundary-spanning activity. This duality has been reported at different levels of analysis and in different study contexts. To name just a few:

- in their important studies of productivity of scientists in industrial R&D (situated at the micro-level of the individual scientist), Pelz and Andrews (1967) point to the existence of different creative tensions, some of which can be reduced to the basic dilemma or paradox just described: how does a scientists handle the balance between striving to become still better embedded in the expertise area (read: community) in which he or she already excels versus breaking away from these established routines, beliefs and artefacts to embrace new research trails? This is succinctly described in Garud's study (1994) on the evolution of cochlear implant technology: *"Researchers develop specific competencies over time. These competencies accumulate in a path-dependent manner as earlier technological choices direct future options and solutions (Cohen and Levinthal, 1990; Arthur, 1988; David, 1985). As competencies become more specialised, researchers find it increasingly difficult to redirect themselves to pursue other paths. This is similar to the notion of the accumulation of "sticky" resources (Ghemawat, 1991). As a consequence, there are powerful incentives for researchers to persist with a path. In this way, beliefs are externalised as artefacts, which in turn shape the beliefs of the researchers associated with the development of these artefacts."*

  Similar phenomena have been reported by Allen and Marquis (1963) and Allen and Frischmuth (1969) when they investigated the 'biasing' effects of prior engineering experience on the problem-solving strategies pursued by engineers. Werth's 1994 description on the development of rational drug design technology again

raises similar issues and dilemmas. In other words, the confrontation between path-dependent activities versus boundary-spanning activities has been present at least in an implicit (but sometimes also in a more articulated) manner in quite some writings on the problem-solving activities of innovative professionals;

- at the project level, research on the Not-Invented-Here syndrome (Katz and Allen, 1982) points to the same tension between path-dependency of the project team versus openness of the project team toward new signals from other stakeholders both within and outside their respective organisations. These boundary-spanning dilemmas have been amply documented ever since (e.g. Wheelwright and Clark, 1992). In 1993, Ralph Katz' case study on the development of the Alpha-chip at Digital provided yet another illustration of the paradoxical nature of the boundary-spanning activity between different communities within one and the same organisation;

- at higher levels of analysis, scrutinising the development of new technologies, the analyses by Constant (1980) on the development of the turbojet, by Thomson on the development of mechanised shoe production (1988), by Garud (1994) on cochlear implant technology or by Burgelman (1994) on Intel's exit from the DRAM-industry all point to technological paths and directions taken or to be taken as being the result of interactions between different communities. In line, Bijker's social constructivist approach (1994) to decision making on technology development and technological evolution highlights this as a process where the confrontation of the beliefs, routines and artefacts characteristic of and held by various communities are re-evaluated, re-negotiated and fused into a synthesis of beliefs, routines and artefacts around which a new community coalesces that may partially or completely include the members of the communities previously present in the complex negotiation and fusion. It is quite comforting to find that studies on the development of new scientific disciplines have since long been confronted with these dynamics and can therefore serve as a useful guiding-post to any student trying to approach the development of new technology and its subsequent embedding in an innovation endeavour from this same perspective. Just to name a few: Ben-David's work in the 1960s on the development of innovations in medicine and the origins of psychology as a "new" science, Edge and Mulkay's 1976 study on the development of radio astronomy, or still, Lemaine et al.'s (1976) work on the origins of new scientific disciplines.

Hence, the dilemma raised in this introduction is not new and can be recognised in different settings at different levels of analysis. Innovation, whether studied as the development of new technological or scientific knowledge, or the creation of new artefacts, is a process that requires spanning and crossing boundaries across communities. Communities have their own fixed set of beliefs, evaluation routines and artefacts that create powerful path-dependencies inhibiting the very boundary-spanning activity that is at the heart of many "successful" innovations as they have been described and documented in the extensive amount of research that has been briefly touched upon above.

Therefore, the starting point of our paper is that our understanding of the innovation process can be further enhanced by framing the innovation process as a *community-spanning process*. As a consequence, the first issue we want to address in this paper is to show and describe (using one specific case study) how we can study, identify and clarify the innovation process from a community-spanning perspective. This, though, immediately

raises a second, still more important, issue. In order to successfully accomplish an innovation effort, community-spanning activities and processes cannot go on indefinitely, though they need to converge to a particular outcome by means of closure, fusion or synthesis. Hence, any study of the innovation process as a community-spanning process needs to address the critical question of *community-spanning strategies*.

But, as communities are characterised by different beliefs, routines and artefacts once they become involved in an innovation endeavour, community-spanning interactions will necessarily be marked by ambiguity. Ambiguity or equivocality implies much more than "uncertainty." Ambiguity means the innovation effort is underdetermined both in terms of its relevant parameter space and in terms of the relationships among the parameters. Uncertainty, on the other hand, implies that the parameter space and its interrelationships are determined, but under-specified: their values or specifications are lacking and need further problem-solving activity.

In order to handle this ambiguity, actors belonging to different communities are required to develop a detailed and in-depth understanding and appreciation of each other's beliefs, evaluation routines and enabling artefacts. Sofar, we have only reached a limited understanding on how we might handle this ambiguity during technological innovations (whereas the relationship between information, information exchange and uncertainty has received much more attention and has been much better articulated). As a consequence, any study on community-spanning strategies will have to focus on the way in which particular strategies to cope with ambiguity can be developed. These community-spanning strategies will therefore have to consider the following central questions: (1) in what contexts can what levels of ambiguity be tolerated and (2) what are the different mechanisms to deal with this ambiguity.

These are the broad issues we want to address in this paper. We start investigating them at one particular level of analysis, that presented itself as a very convenient starting point for our current research interest: the development of a new chemical process for metallurgical refining. We therefore first need to tell the story on the development of this process. Our ideas and assumptions on community-spanning processes and strategies will be developed along this narrative. By way of setting the stage, they can be briefly summarised by the following propositions:

P1: Community-spanning interactions are required to break the deadlock of path-dependency within a particular community of innovation practice.

P2: Community-spanning interactions that allow for these structural breaks are embedded in community-spanning strategies. The central focus of these community-spanning strategies is on the variety of potential modes to handle ambiguity. This ambiguity stems from the diversity of beliefs, evaluation routines and enabling artefacts that create community-specific path-dependencies. These strategies are concerned with (1) the levels of ambiguity that can reasonably be handled given the context in which the interaction is or will be embedded and (2) the specific mechanisms to handle this ambiguity from an organisational point of view.

Hence:

P3: Handling ambiguity during community-spanning interactions requires a context-specific assessment of the levels of ambiguity that can successfully be tolerated at any point in time and space, given the community-specific context of the actors drawn into (or to be drawn into) the process.

P4: Levels of ambiguity that can be tolerated will be dependent upon as well as defined by the mechanisms to handle ambiguity that can be deployed. Major mechanisms are: (temporary) withdrawal, co-operation, and confrontation. These basic mechanisms can be moderated through the use of technical fixes or artefacts (e.g. experimentation, simulation, prototyping routines, ...).

Narrating and reconstructing the 'purification'[1] process : a typical story[2] on engineers and scientists and their beliefs when constructing an innovation

On October, 19th 1994 an R&D-project concerning the 'purification' phase of the production of {*products name*} was presented and approved by a cross-functional committee. Both the R&D department and the Business Unit involved agreed on the objectives and the approach to scout, examine and evaluate opportunities to improve the 'purification' step in the existing process.

This approval signals the coalescence and the translation of the various ideas on purification process improvement that had been circulating for a while amongst the different stakeholders into a dedicated budget, action plan and assignment of experts to work on the approach chosen.

This new project definition was not unheard of, though. Already in the period 1992-1993, various groups (read: communities) within the company had started to look at the 'purification' process. The main motivation for these efforts (at that time) resided in the evolution of world market prices for {*products name*}. At the Business Unit, though, these efforts awakened mixed feelings. The hope for a really path-breaking result were almost non-existent. After all, eighty-five percent of the world's {*products name*} is produced under a licence using the very process they themselves developed 20-30 years ago. Obviously, the refining technology and process they had developed, had paid off nicely for the company.

Not only for the company had the pay-off been handsome. Their personal careers had benefited as well. The process champions of thirty years ago had all risen to senior management positions in the Business Unit. They were running the show. They knew what was important in further developing the refining process. Still more important, they had realised a process that had earned their corporate parent over the last two decades a pay-back

[1] 'Purification' refers to a stage in the (chemical) production process of {*product name*}

[2] This 'story' is a first reporting on an ongoing research project focusing on interaction strategies during the development process. As interviews and observations are still going on, only a more global description of one of the development processes under study is sketched here. The quotes interwoven in the description of the different events all stem from the R&D project manager. More rigorous and systematic descriptions of the process at hand, including other involved 'voices', are being worked out. The process described here is situated within a European -based multinational non-ferrous group producing over twenty different types of non-ferrous metals.

ratio of about 400 on the initial R&D investment required to develop the refining process. So, would a path-breaking view on the refining process ever be possible? Certainly not! At best, the improvements would come from improved process control and instrumentation. This was a logic cognitive step to this pioneering development community. Indeed, when they first pioneered the process in the 1950s and 1960s, electronics and instrumentation did not exist. At best, they then were theoretical leaps, with no engineering implications at all. The younger generations of their profession, who had been raised with microprocessors and computers thus better might have look at this type of process improvement. In this way, the technological trajectory they envisioned and created several decades ago, would be extended and the success story would further be reinforced.

As a consequence, during this first period efforts of the refining project, efforts were devoted to the first stages of the process. No clear prospects for improvements or breakthroughs were defined nor anticipated. The only certainty existed in that the Business Unit advocated that a rigorous approach be followed. In 1994, the need to do something more specific, leading to more tangible short term results, was becoming acute to the Business Unit (BU). Fierce competition threatened the companies position in the product market. In addition, major competitors spread rumours about realising productivity gains in the range of 20 to 50 % by applying more efficient processes. This was done - so they claimed - to a large extent by better process control. The improvement leap was doubted by the BU (were not they at the origins of the world's leading process?); however the instrumentation avenue, as already described, was taken seriously enough to consider the possibility. So the 'five year' approach was redefined and resulted in the project as approved on October, 19th, 1994.

As a first step, the project manager (PM) assigned to the project started a large information round during the first months of 1995. The project manager was an experienced R&D collaborator. He visited everybody within the company, assumed to possess knowledge relevant to 'purification.' This information round consisted of bi-lateral and informal talks.

"Bringing everybody together would be inefficient and time-consuming. Moreover, as I was trying to establish for myself and my team a more profound insight in the process under study, I would not like to become involved in a 'power game' between different experts, all with their own agendas and preferences. You must not forget that this organisation has grown out of several independent companies that used to be competitors; old rivalries are still present from time to time, especially on occasions where the question 'who is the real expert here' is posed. Bringing them all together opens the risk of an escalation."(excerpt from interview)

The main objective for the project manager at this stage was to get a clear insight in the underlying chemical processes, the methodology to be followed and the possible options for improvement. In the project definition, an exhaustive list of possibilities was listed totalling in the neighbourhood of twenty different options or solution possibilities. The PM was looking for clues to organise and prioritise these different options. On the side of the BU this broad exploratory stage was not needed to know where possible profits could be found; one specific

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The group has production facilities in Europe and the US . In 1995 the group reported a turn-over of 4.0 billion US$ and employed about 13,000 people world-wide.

option - recycling - was considered the most fruitful, besides the instrumentation strategy. This point of view was communicated to the PM.

Co-ordination between the BU 'community' and the R&D 'community' in the company at this stage was experienced by the PM as rather directive:

"They wanted me to just look into the recycling option; everything else was considered of minor importance or even a waste of time. So I had no choice but spending the first three or four months of the project on doing experimentation related to recycling. Although I did not believe it was going to be really leading to something worthwhile." (excerpt from interview)

So the many alternative options described in the project plan stayed in the refrigerator for a while. In March 1995, a first intermediate report on the recycling option was presented to the BU. These results of the first months of experimentation made clear that working on recycling was no viable option:

"This step gained me time; I spent the first three months only on recycling, doing experiments and so on. Now the results made clear that solutions would have to be found elsewhere. By writing this report I get them off my back. I agree that R&D should be customer-oriented; on the other hand, a researcher needs certain degrees of freedom to explore new possible options even if their outcome is unknown. The first months the BU was really directive towards our work; they did not stop to tell us what to do and how to do it. Now we had proven that recycling would not work, they lost interest; they left us doing the project without dictating how to proceed." (excerpt from interview)

The project was not ended at this stage though; the project definition included a whole range of options and a project plan for two years. The findings on recycling did not lead to an abrupt ending of the project: *"Commitments were made; the project definition at the start was broader than mere recycling. So now we could work systematically on the whole range of possibilities that was defined." (excerpt from interview)* The manager of the R&D department fully understood this need and furhter shielded his R&D collaborators from undue BU meddling.

In the months to come a full experimental set-up was constructed and adequate process control equipment was installed. During summer, further reports were produced containing preliminary results on the different options.

"These reports certainly had an impression management aspect to them; we were communicating that we were busy with a whole range of viable options. So at the BU level they regularly noticed that we were busy; that the project was not in a dead end street." (excerpt from interview)

During this period a ' strange' series of events was registered when rigorously monitoring the experimental runs. *"By coincidence we noticed that minor shifts in the temperature created some unexpected side-effects. Having a rigorous research method allowed us to detect this. You are nowhere without a rigorous research approach.*

Examining this phenomenon more closely revealed that the presence of {chemical substance} had some influence. However the nature of the impact on the 'purification' process was unclear." (excerpt from interview)

During the summer a new intermediate report was made, resulting in a September meeting between R&D and the BU. An overview of different action strategies was presented. They were organised in terms of priorities as perceived by the BU.

"If you look at the presentation of September 29th ... we have described and organised the five different options in order of their preference; and read this... 'parallel with the five described options we will explore the possibilities of stabilising the process by adding {chemical substance} to the process.' We were not sure that it would lead to anything at that stage but the observations done so far made us believe this could become something 'big'. However we did not want to come out with this yet; the chances were high that the idea would be killed right away. By stating it in this way, we managed to continue our explorations in that direction as well." (excerpt from interview)

The next six months were spent working rigorously on the different options. The project manager devoted a lot of effort to the 'sixth' (bootlegging) option as well. During this time period no 'official' interaction with the BU took place. *"The observations we made on these strange 'side-effects' just kept me busy. It could be the case that the same mechanisms were applying here as were very well known in the {application name} area. So I started to discuss this possibility with {name}, a real expert in {application name}. He selected a list of about 25 powders; we started to test systematically whether they had any impact on the process. And two of them really did. So, after two months, we knew we had hit upon something really good. We had identified two elements; and the best effects were obtained when combining them." (excerpt from interview)*

This did not mean the other options were neglected: "*We worked on all options quite simultaneously. However - while progressing - it became clear that the major breakthrough would lie with the sixth option, implying savings of several millions of dollars a year. But we also worked out some serious improvements for the agitation part of the process; this resulted from the development of the second option." (excerpt from interview)*

In March 1996, the first results related to this option were presented at an R&D meeting. It became clear that the findings were plausible and viable. However still no one from the BU was present at that meeting. *"When we knew that the addition of {chemical substance} and {chemical substance} could lead to a serious improvement of the process, in terms of effectiveness as well as efficiency, we still needed to define the optimal doses. As this might sound like an easy question, finding the answer is definitely something else. We would not go to the BU before we had determined the optimal doses and had done a whole series of experiments so that the robustness of the phenomenon was indisputable. If we would not have this kind of data, they would have blown us away." (excerpt from interview)*

On June 19th the findings were presented at the BU. What was planned to be a one hour meeting between four and five p.m., took till nine p.m. *"They could not believe that these results came out of it, but the evidence was there. We had to explain it over and over again." (excerpt from interview)*

A final report was written in November last year; the findings were presented at the corporate level and during the 1996-1997 budget meetings as well. The implementation phase is being worked out right now.

"Of course I would like to have worked together with the BU in another way. But collaboration in such a project means other things to me. We needed feed-back, not directives. If I had been working with other people, the interaction might have been completely different. Working with {other BU manager's name} for instance is completely different. I keep him informed on all findings in each stage. He takes time to listen and to brainstorm, to explore." (excerpt from interview)

Whether the outcomes would be different when the interaction with the BU would be otherwise? *"I guess so, but we can not know this for sure, can we?"*

Looking at the 'purification' process from a community perspective

As described in the introduction to this paper, the notion of a community is highly relevant to look at the evolution of scientific disciplines and technological developments. Communities and communal behaviour can be relevantly defined at different levels of analysis. Communities are 'collectivities,' sharing beliefs, hopes and search heuristics. As a consequence, communities as a concept are to be linked to the notion of 'problem domains' as developed by Trist (1983): 'Functional social systems which occupy a position in social space between the society as a whole and the single organisation'. Technological communities, for instance, can be seen as the group of scientists and engineers, who are working towards solving an interrelated set of technological problems and who may be organisationally and geographically dispersed but who nevertheless have a shared interest and hence communicate with each other. (Debackere and Rappa, 1994). Underlying the relevance of the notion of community lies the idea that scientific and technological developments are inherently social as well: "While it is true that that scientists grapple with nature, they also grapple with each other" (Rappa and Debackere, 1995, p.324). Or, as pointed to by Medawar (1967), science is the art of the soluble. Good scientists work on the problems they *believe* they can solve and that are relevant (read: judged important enough) by their 'peer' community. This idea comes close the cycle of credibility as it has been developed by Latour and Woolgar (1982).

However the notion of communities can be extended to other, micro-levels of analysis too; it then refers to collectivities that share an understanding of a problem domain. Whereas Lave and Wenger (1991) define communities mainly in terms of stability[3] a certain degree of homogeneity in terms of problem approach and understanding seems to characterise them as well. One can speak of homogeneity not only at the level of cognitive frames (Miller et al., 1996), but as well in terms of identity. It is in this latest sense that we use the notion of community. This collectivisation of identity is closely related to Garud's shared beliefs, evaluation

[3] "A community of practice is a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice." (Lave and Wenger, p. 98)

routines and artefacts embraced by the community's actors. As a consequence, communities are powerful devices for path-dependent thinking. This is well illustrated by the attitudes and reactions of the BU pioneer community to the new purification development. Extending on Weick's dilemma of organising versus learning, one might hypothesise that 'new' communities are born as the result of a learning experience. However, once communities organise and institutionalise, emphasis shifts from creation to proliferation. This proliferation engenders routinisation and conformity, thus generating powerful path-dependencies or lock-in phenomena making it increasingly difficult to break away from the path.

As Brown and Duguid (1991) take the notion of community as a starting point to establish a connection between working, learning and innovating, we now discuss and apply their approach when 're-writing' the case. As mentioned in the introduction, we will argue that path-breaking innovations necessarily imply an interaction spanning the boundaries of different communities within (and even external to) the organisation. This community-spanning interaction figures as the pathway to understand the optimisation of the 'purification' process. We also suggest this interaction has important implications as to the strategies that are to be deployed when attempting at spanning different communities. During the innovation process, boundaries between communities need to be crossed while at the same time, new frames of understanding --generating eventually new 'communities.' As shown in the brief case development, these community-spanning strategies, like DNA, may consist of a limited set of building blocks: (1) temporary withdrawal from communities that become to belligerent, (2) confrontation between communities, and (3) co-operation and joint problem-framing and -solving. Just as the four basic DNA building blocks, by their spatial sequence and interaction, are at the basis of an almost unlimited variety of living species; so may the spatial *and temporal* sequence of the three community-spanning mechanisms create an almost unlimited range of options available to engage in community-spanning interactions. In addition, the presence of "new" experimentation techniques and technology may further moderate the sequence and applicability of these community-spanning mechanisms *(note: this is a proposition which we derive from the case study, but which needs further development in our present research).* This hypothesis is suggested by the temporal, experimentation-based withdrawal from the R&D community as to its interactions with the BU community.

Towards a unified view of working, learning and innovating: communities as the 'vehicle' for path creation and ... as an 'origin' of path-dependencies ...

Brown and Duguid take a systematic look at the processes of working, learning and innovating. Eventually they argue that the same underlying processes are important for all three activities.

As to working, the research of Orr (1996) provides a starting point. Taking into the account the tension between canonical practice, the explicit or 'official' knowledge and way of acting, and non-canonical practice, as well as the actual way people perform their activities, Orr's ethnographic work allows to derive three central features of work practice: narration, collaboration and social construction.

The first aspect of work practice worth highlighting is the extensive narration used. The stories reflect the complex social web within which work takes place and the relationships of the story teller, the story and the audience. Creating and exchanging stories has two important aspects. First of all, stories help to diagnose the problem at hand. Second, the stories become a mean to preserve knowledge; they figure as repositories of accumulated wisdom that circulate within the community of practitioners. Stories help to relate beliefs, routines and artefacts.

A second main characteristic of work lies in the notion of collaboration; the narrative process described above is a collective, not an individual process. Faced with difficult problems people work together and discuss problems in groups[4]. This makes working an inherently social process that benefits from collaboration. Brown and Duguid here make an analogy with the concept of 'bricolage' - the ability to 'make do with whatever is to hand' - as developed by Lévi-Strauss: *"what one needs for bricolage are not the partial, rigid models of the sort directives or rigid documentation provides, but help to build, ad hoc and collaboratively, robust models that do justice to particular difficulties in which one find themselves."* So, exchanging, developing and adapting stories plays a crucial role in the process of knowledge, expertise and skill development. This activity, however, implies the free-floating of these stories, the willingness to share, to listen and to engage in a constructive dialogue. In short, this implies collaboration.

Finally, telling stories contributes to the (social) construction and development of one's identity. This also means contributing reciprocally to the construction and evolution of the community that one is joining.

As for learning, Lave and Wenger's concept of *Legitimate Peripheral Participation* is brought in by Brown and Duguid. Whereas conventional explanations of learning stress internalisation - whether discovered, transmitted from others or experienced in interaction - Lave and Wenger approach learning as a process wherein one is involved as a person and which is situated in practice. By doing so, they leave the sharp dichotomy between inside and outside behind. Legitimate peripheral participation is not itself an educational form; it should be understood as an analytical viewpoint on learning, a way of understanding learning.

This concept developed by Lave and Wenger (1991) denotes the particular mode of engagement of a learner who participates in the actual practice of an expert, but only to a limited degree and with limited responsibility for the outcomes. Learning is seen not as merely the reception of factual knowledge or information; but as a process of participation in communities of practice; participation that is at first legitimately peripheral but increases gradually in engagement and complexity. Learning as legitimate peripheral participation means not to receive or even construct abstract 'objective' individual knowledge but involves becoming an insider. One becomes member of a community - be it a community of physicists, class mates or scholars in philosophy or organisational behaviour. Community membership hence is not so much an issue of being as it is a process of becoming.

Conceiving learning in terms of participation, focuses attention on the ways in which it is embedded in an evolving, continuously renewed, set of relations. This view also claims that learning, thinking and knowing are relations among people in an activity, in, with, and arising from the surrounding (socially and culturally

[4] See also Weick's view on the relation between equivocality and interaction (Weick, 1979).

structured) world. A world that is socially constituted; *"systems and structures of activity on the one hand and agents' subjective and inter-subjective understandings on the other hand, mutually constitute both, produce and reproduce each other recursively."* Knowledge of the socially constituted world is socially mediated and open-ended. Given this relational view, participation can neither result in fully internalised knowledge structures nor in fully externalised instrumental artefacts or overarching activity structures. Participation is always based on situated negotiation and re-negotiation of meaning in the world. So understanding and experience are in constant interaction.

Participation in social practice suggests also a very explicit focus on the person, but as person-in-the world, as member of socio-cultural community. Learning implies not only a relation to specific activities but also a relation to social communities; it implies becoming a full participant, a member, a kind of a person. Activities, tasks, functions and understandings do not exist in isolation; they are parts of wholes in which they have meaning. The systems of relations arise out of and are reproduced and developed within social communities, which are in part systems of relations among persons. The person is defined by as well defines these relations. By means of participation, reflective moments can be brought in this ongoing process; these trajectories always being situational (Lave and Wenger, 1991, p.50- 56, see also Giddens, 1979 & 1984).

When juxtaposing both approaches - Orr's description of work practice and Lave and Wenger's viewpoint on learning as legitimate peripheral participation - similarities become apparent. In both cases 'tensions' give rise to developmental activities situated in a social context. Collaboration can be seen as in line with the notion of legitimacy; the process of narration in the case of diagnosis as described by Orr comes very close to the process of peripheral participation.

When discussing innovation, Brown and Duguid introduce the framework of Daft and Weick on interpretative innovation (Daft and Weick, 1984). Daft and Weick propose a matrix of different kind of organisations, each typified by its relationship to its environment[5]. Two of them can be seen as 'innovative' organisations. The discovering organisation is the archetype of the conventional innovative organisation; responding to changes it detects in its environment. The enacting organisation on the other hand is depicted as proactive. It does not only respond to its environment, but also creates the conditions to which it must respond. Innovation, then is not simply a response to empirical observations of the environment; as the source of innovation lies in the interface between an organisation and its environment. The process of innovating involves actively constructing a conceptual framework, imposing it on the environment and reflecting on their interaction. (Brown and Duguid, 1991).

Brown and Duguid argue that the actual non-canonical practices of communities are continually leading to new interpretations of the world because they have a practical connection to the world. Closure is the likely result of the rigid adherence to formal practice. Rejecting a pre-determined view and constructing through narration an alternative view is seen as essential to innovation. By doing so, an enacting organisation must be not only capable of re-conceiving its environment, but also its own identity, as the two are in a significant sense mutually constitutive. *"This re-conceptualisation is something that people who develop non-canonical practices are*

[5] These relationships are labelled undirected viewing, conditioned viewing, discovering and enacting.

continuously doing, forging their own and their community's identity in their own terms so that they can break out of the restrictive hold of the formal descriptions of practice. Enacting organisations similarly regard both their environment and themselves as in some sense unanalysed and therefore malleable. They do not assume that there is an ineluctable structure, a 'right' answer, or a universal to be discovered; rather they continually look for innovative ways to impose new structure, ask new questions, develop a new view, become a new organisation" (Brown and Duguid, 1991).

... and thus path dependencies originate ...

The tension between the 'prescribed' or canonical view on the purification process - as developed within the BU community over a twenty year time period - and what actually is observed during the first experimentation round triggers development efforts within the R&D team. Also collaboration among actors is constitutive for the developments during the process. In this case, a variety of interactions between *different* communities was essential. The development efforts - especially with regards to the sixth option - result in a breakthrough because of the joint effort of two communities; the R&D team and the specialists within the 'application' department. Striking here is that people belonging to the BU community are left out during this particular phase and that this 'temporary withdrawal from interaction' is experienced as crucial to advance.

As a consequence, community-spanning interaction does not present itself neither develop in a straightforward, linear sequence of steps and actions. On the one hand the innovation process can benefit from bringing in new perspectives by spanning the boundaries between communities. At the same time, introducing new perspectives challenges the existing order of beliefs, routines and embraced artefacts. As identity is at stake, this could be seen as a profound and even painful process implying reactions of denial, rejection and aggression. Withdrawal then becomes necessary to allow advancement. Balancing between the both ends of the spectrum - openness and closure - implies complex strategies to span the boundaries between communities. As suggested at the outset, though, these community-spanning strategies, critically hinge upon the levels of ambiguity that are tolerated and can be handled between different communities.

A new look at the purification process as a sequence of openness and closure between communities

In the Table, the different stages, actors, options as well as interaction characteristics are summarised.

Insert Table :Revisiting the 'purification' story: Phases, actors, opinions and interaction characteristics

Three 'communities' can be distinguished along the 'purification' process: (1) the engineering community responsible for running the operations within the Business Unit , (2) the 'research' community consisting of the R&D team responsible for working out the project and finally, (3) the 'application' community playing a role in the development of one of the options. It becomes clear that the ways in which the communities interact and collaborate alters from phase to phase. Different 'assembly' rules are used at different stages (Weick, 1979); not

only the perceived equivocality related to the task is influencing the choice of these assembly rules, the experiences during the different interactions also lead to changing the applied rules. Upon experiencing the interaction between his team and the BU {*product name*} as directive and one-sided - and hence destructive for his attempts to take a fresh look at the 'purification' process- the project manager shifts towards an 'impression' management-type of communication with this community.

By doing so, he avoided in-depth discussions and a potential damaging confrontation with the dominant logic of a powerful community. The early observations when developing a full experimental process set-up led to interactions with another community. This community was regarded as experienced with the phenomena under observation. Also, because of the experiments conducted in isolation by the R&D team, the level of ambiguity between both communities was tolerable so that co-operation became a viable community-spanning strategy. Eventually this community-spanning co-operation resulted in a serious breakthrough. Hence, the sequence of community-spanning interactions might be summarised as follows:

stage 1:	BU directs R&D project team, the community-spanning strategy almost has a confrontational character
stage 2:	R&D temporarily withdraws from interaction with the BU, experiments 'in isolation' help reduce ambiguity
stage 3:	application community is drawn into co-operation with R&D community at acceptable levels of ambiguity
stage 4:	R&D community confronts the BU community with its co-operation results
stage 5:	emergent co-operation between the R&D and the BU community

It seems not very fruitful to start guessing about what might have happened when the project manager and his team and the BU would have interacted in a different way. However we do want to explore the dynamics underlying the interaction sequence just analysed.

We already referred to Garud's work on technological evolution. We argued that communities are collectivities of individuals sharing beliefs, evaluation routines and artefacts. In doing so, communities are like Plato's prisoners. They create their own reality, their own identity, their own truths or paradigms. As a consequence, interactions between communities that do not share the core set becomes increasingly difficult, the larger the distances between these core sets of beliefs, routines and artefacts. These distances are at the origins of the ambiguity that exists between different communities.

This notion of truth - in a pragmatic sense - makes it understandable why bringing in new perspectives is often an hazardous enterprise, as this notion of truth is inherently linked to the notion of identity or 'absorptive capacity' at the micro-level.

James (1907) - building on the insights of Dewey and Schuler - provides us with the following definition of truth:

'Truth' in our ideas and beliefs means the same thing that it means in science. It means *that ideas (which themselves are but parts of our experiences) be come true just in so far as they help us to get into satisfactory relation with other parts of our experience.* (W. James, p. 24) ... In this context, we are also reminded of

Medawar (1967) who stated that 'science is the art of the soluble.' Scientists choose the problems they believe they can solve.

This view on truth is derived from examining situations whereby individuals settle into new opinions (as is the case in innovation efforts). Analysing this phenomenon leads to the demarcation of the following dynamics:

"The individual has a stock of old opinions already, but he meets a new experience that puts them to a strain. Somebody contradicts them; or in a reflective moment he discovers that they contradict each other; or he hears of facts with which they are incompatible; or desires arise in him which they cease to satisfy. The result is an inward trouble to which his mind till then had been a stranger, and from which he seeks to escape by modifying his previous mass of opinions. He saves as much of it as he can, for in this matter of belief we are all extreme conservatives. So he tries to change first this opinion, and then that (for they resist change very variously) until at last some new idea comes up which he can graft upon the ancient stock with a minimum of disturbance of the latter, some idea that mediates between the stock and the new experience and runs them into one another most felicitously and expediently. This new idea is then adopted as the true one. It preserves the older stocks of truth with a minimum of modification, stretching them just enough to make them admit the novelty, but conceiving that in ways as familiar as the case leaves possible." (W. James, p. 24).

The 'inertia' or notion of path dependency figures prominently in this account on truth. James stresses the importance of older truths as they might hinder the adoption of new insights (cf. the first confrontation between the BU community and the R&D community). Bringing in perspectives too ambiguous and hence too distant from existing knowledge will result in denial or rejection:

"An outrée explanation, violating all our preconceptions, would never pass a true account of novelty. We should scratch round industriously till we found something less eccentric. The most violent revolutions in an individual's belief leave most of his old order standing. Time and space, cause and effect, nature and history, one's own biography remain untouched. New truth is always a go-between, a smoother-over of transitions. It marries old opinion to new fact so as ever to show a minimum of jolt, a maximum of continuity. We hold a theory true just in proportion to its success in solving this problem of maxima and minima. But success in solving this problem is eminently a matter of approximation. We say this theory solves it on the whole more satisfactorily than that theory; but that means more satisfactorily to ourselves, and individuals will emphasise their points of satisfaction differently. To a certain degree, therefore, everything here is plastic. The point I now urge you to observe particularly is the part played by the older truths. Their influence is absolutely controlling. Loyalty to them is the first principle - in most cases it is the only principle; for by far the most usual way of handling phenomena so novel that they would make for a serious rearrangement of our preconceptions is to ignore them altogether, or to abuse those who bear witness for them." (W. James, p.25).

When it became clear that the R&D team and the project manager had their own opinion on a suitable approach (methodology) and are looking for new ways to conceive of the process (theory), efforts are undertaken by the BU to impose their view. When these attempts to influence the action of the R&D team in the direction of their own opinions - i.e. creating homogeneity in terms of the view on what the process was about (theory) and how to

approach this project (methodology) - failed, the interaction becomes minimal. The BU looses interest, starts to 'ignore' the development efforts. From the side of the R&D community, this loss of interest is not really seen as a problem. In the light of their previous experience towards to the collaboration with the BU, looking for shelter was seen as the next thing to do. Within the R&D community, the risk of "getting abused when bearing witness of new conceptions" was clearly acknowledged : "We would not go to the BU before we had determined the optimal doses and had done a whole series of experiments so that the robustness of the phenomenon was indisputable. *"If we would not have this kind of data, they would have blown us away*."

Obviously, changing paths or trajectories in technological development is a major challenge. Indeed, modification of opinions has been documented as a profound process (Steyaert et al., 1996). This is what occurs along the technological development trajectory as well. Path-breaking innovations indeed require a re-thinking of community members' perceived truths and hence, a re-configuration of their own identity as persons who are totally involved in and devoted to their practice (Lave and Wenger, 1991). It is not astonishing then that a powerful, almost cumulative, inertia is at work, which increases probably exponentially the better and the longer people are embedded in their respective communities (Rappa, Debackere and Garud, 1992).

However, as was clearly demonstrated in the case, communities do not only create important forces of inertia, though their interactions and confrontations are at the origins of breaking away from well-known paths and trajectories as well. These confrontations are not random, though. Actors in a particular community cross the boundaries of their community by looking for partners in other communities who are believed to have an affinity with the ideas or insights to be developed (Giddens, 1979&1984). The different community-spanning strategies discussed and developed in this paper demonstrate that actors look for the construction of temporal 'zones of proximal development' (Vygotsky, 1986). If this common ground cannot be found (temporarily), then withdrawal is a strategy to be advised.

Hence, the paradoxical nature of the innovation process as a community-spanning process. Communities can be the very locus of path-breaking developments thus breeding the path-dependencies of the years to come. Hence, to conclude, we believe we have provided some evidence for the propositional framework we outlined at the outset of this paper. They are at the heart of our research agenda for the years to come.

P1: Community-spanning interactions are required to break the deadlock of path-dependency within a particular community of innovation practice.

P2: Community-spanning interactions that allow for these structural breaks are embedded in community-spanning strategies. The central focus of these community-spanning strategies is on the variety of potential modes to handle ambiguity. This ambiguity stems from the diversity of beliefs, evaluation routines and enabling artefacts that create community-specific path-dependencies. These strategies are concerned with (1) the levels of ambiguity that can reasonably be handled given the context in which the interaction is or will be embedded and (2) the specific mechanisms to handle this ambiguity from an organisational point of view. Hence:

P3: Handling ambiguity during community-spanning interactions requires a context-specific assessment of the levels of ambiguity that can successfully be tolerated at any point in time and space, given the community-specific context of the actors drawn into (or to be drawn into) the process.

P4: Levels of ambiguity that can be tolerated will be dependent upon as well as defined by the mechanisms to handle ambiguity that can be deployed. Major mechanisms are: (temporary) withdrawal, co-operation, and confrontation. These basic mechanisms can be moderated through the use of technical fixes or artefacts (e.g. experimentation, simulation, prototyping routines, ...).

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Revisiting the 'purification' story: Phases, actors, options and interaction characteristics

Phases:	Project definition	Designing a problem solution approach - Exploring recycling option	Exploring different options	Pursuing viable options	Drawing conclusions towards implementation
Period	< 24.10.94	25.10.94 - 03.95	03.95 -29.09.95	29.09.96 - 18.06.96	19.06.96 - 12.96
Actors involved	Mainly BU {*product name*} & R&D Competitors: Rumours of performance improvements as a trigger for focus/ redefinition	R&D, PM and his team BU {*product name*} R&D and 'local 'experts.	R&D, PM and his team BU {*product name*} BU {*application name*}	R&D, PM and his team	R&D BU {*product name*} Corporate levels
Options taken into consideration	Broad range of options and ideas, related to different concerns and viewpoints	List of +/-twenty possible options	Grouping of actions/possibilities into six 'broad' classes	Working out technical steps for different options. Focusing on 'sixth' option as well as on possibilities for agitation.	Two options found worth implementing: adding {*element*} and {*element*} + agitation
Interaction characteristics	Constructively combining efforts based on parallel interests.	Directive - one-sided between R&D-BU {*product name*} Informal, open between R&D and local experts	R&D providing BU {*product name*} with feed-back as to give the impression that 'everything is running well'. Between R&D and BU {*application name*} open and constructive	R&D remaining 'silent' as to build 'strength of argument' before entering the 'presentation' stage	R&D convincing BU by means of an 'expert' approach.