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Communication and learning structures that facilitate transfer of knowledge at innovation transition points

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ABSTRACT: Innovation processes are rarely smooth and disruptions often occur at transition points were one knowledge domain passes the technology on to another domain. At these transition points communication is a key component in assisting the smooth hand over of technologies. However for smooth transitions to occur we argue that appropriate structures have to be in place and boundary spanning activities need to be facilitated. This paper presents three case studies of innovation processes and the findings support the view that structures and boundary spanning are essential for smooth transitions. We have explained the need to pass primary responsibility between agents to successfully bring an innovation to market. We have also shown the need to combine knowledge through effective communication so that absorptive capacity is built in process throughout the organisation rather than in one or two key individuals.

Context and objectives

It has been argued that innovation is a process that can be managed and there are characteristic evolutionary stages that can be identified[1]. Empirical data suggests there are issues in making the transition between stages. Beckett and Hyland[2] maintain that the external and internal environments influence how both the stages in the evolution of an innovation and how transitions between the stages are enacted. Our long-term research objective is to find ways to more effectively manage transitions in the innovation process.

Geels and Schot[3]articulated four transition pathways that depended on whether internal or external resources dominated. They also observed that multiple types of agency are involved in most transitions. The involvement of multiple agents creates added complexity at the transition points as there is rarely a shared view of the interaction and there are inevitable differences in language and understanding as engineers interact with research scientists and researchers interact with management and marketing practitioners. This potential problem of misunderstandings can compromise the successful navigation of a transition and the progression of a particular innovation. The interplay of agency and structure (language in our case) is noted in structuration theory[4], where rules (methodologies and social norms) appear to exist independently, but they are only applied only through use and reproduction in practice. Agents are embedded in social and operational rule structures, but at the same time reproduce them through their actions (‘duality of structure’). At transition points agents also bring some knowledge and some unstated rules with them in the repertoire of schemas that they use to interpret the world, make sense of it and make decisions. Poole and DeSanctis[5] suggested a variant of Giddens[4] structuration ideas they called the theory of Adaptive Structuration to apply those ideas in socio-technical organization settings based upon three functional elements; structuration, appropriation and adoption. Appropriation is defined by Poole and DeSanctis[4] (p16) as, the “…fashion in which a group uses, adapts and reproduces structure.” Adoption is the deep embedding of the structure into the organisation’s process framework. Giddens[7] identified different types of structure. One type is structures of signification that help produce meaning through interpretive schemas, communication and effective translation of overlapping language. Gidden’s other two structure types are legitimisation (sanctioning practice and behaviour) and domination (heirarchy and power).

We explore matters of signification in this paper, along with associated matters of agency, recognising that they co-exist with structures of legitimisation and domination that may influence their enactment.

The research uses a case study approach to present three instances where language and understanding have been critical to the effective transfer of knowledge in the R&D process.

Agents and structures of signification in the innovation process

Several researchers have noted the existence of agents termed intermediaries or boundary spanning agents that facilitate the innovation process. In a structuration theory context, these agents reproduce structures of signification through their actions. According to Tushman and Scanlan[6] boundary spanning agents are individuals who are strongly linked internally and externally and can both gather and transfer information from within and outside their work units. Boundary spanning agents are viewed as communication stars[7] and can effectively communicate widely within their work unit, across work units and outside their organisation. Kellog et al[8] argue that boundary spanning agents are able to act as translators, brokers or mediators. They also argue that cross boundary activities are enhanced by establishing common knowledge or common ground and by using mechanisms such as routines, languages, stories and models that have meaning across the boundaries.

Howells[9] views intermediaries as playing a role in diffusion and technology transfer, in innovation management, as components of the systems and networks of innovation. Howells[9] recognised that not only individuals but also professional bodies can provide some intermediary roles. Bessant and Rush[10] (p 102) noted a broadly similar set of functions carried out by consultants: in the "articulation and selection of technology options: scanning and locating new sources of knowledge; building linkages with knowledge providers, development and implementation of business and innovation strategies highlight the more interactive and diagnostic role of intermediaries". Adler et al[11] maintain that boundary spanners transfer information about changing market and conditions and boundary spanning is linked to the management of technology, innovation, and implementation. If external parties are to be effective intermediaries and span the boundaries between R&D and implementation they need to understand the new technologies and have an effective grasp on the underpinning science involved in the new technologies. In her work in the beef industry in Australia Moreland[12] found that technological innovations with high levels of complexity presented a real challenge to some intermediaries who found the technology too complex and confusing.

Moreland[12] also found that some businesses lacked the competences needed to combine new technical knowledge with operational knowledge. This finding supports the work of Cohen and Levinthal[13] who argue that acquiring technical knowledge through a third party does not guarantee effective technology transfer, rather they maintain that effective absorptive capacity is needed to combine technical knowledge and operation knowledge of "the firm's idiosyncratic needs, organisational procedures, complementary capabilities and extramural relationships" (p 237). Taking this a step further Cohen and Levinthal[13] point out that to use the knowledge and technologies developed in external domains businesses must have acquired "complementary internal expertise" so that they have the necessary capability and capacity to exploit and benefit from new knowledge and technologies. So both the type of knowledge transferred at transitions points is important as are the structures that facilitate the knowledge transfer. Critically the structures and the knowledge must be appropriate for participants in the transfer process on both sides of any transitions point and it is often left to boundary spanning agents to translate the language between the knowledge provider and knowledge recipient.

Drawing on our prior experience with the use of responsibility matrices and the observations of others about requisite communication[6,7,9,10] we have constructed an illustrative communication matrix (table 1) to facilitate understanding what is done by who in each phase of the evolution of an innovation. In the technology stream, opportunities have to be turned into concepts, then products or processes and then into a platform for further growth. In the management stream, opportunities have to be turned into credible investment options, then into a market opportunity, then into an ongoing source of delivered value for both the enterprise and its clients. Along the way, opportunities to adapt the innovation may be identified. At the transition points, the language needs to change from selling a vision (1 to 2), to selling a concept (2 to 3), to selling a product (3 to 4). There will be both technological and management actors involved, with communication required between them. This highlights the complexity of communications required in the exploration and exploitation of an innovation.

Innovation Development Stage	Functional Responsibility	
	Technological	Managerial
1. Identification	Scanning the technology environment, imagining possibilities for emergent technologies	Scanning the market environment, imagining possibilities in emergent client needs and markets, "picking winners"
2. Exploration	Researching and experimenting with ideas, developing concepts, "picking winners"	Finding resources for experimentation and establishing appropriate project management arrangements, developing business models
3. Implementation	Turning ideas into a product or process that can be reliably delivered using minimal resources, "picking winners"	Finding resources for implementation and establishing appropriate project management arrangements, identifying market pathways, meeting cost and schedule targets, "picking winners"
4. Value generation	Using an emergent innovation in concert with current capabilities to build an enhanced enterprise technology platform	Moving from a lead user to a mass user market, establishing product management and support arrangements and accessing extended markets and supply chains

Table 1. The Communication Matrix.

Methodology

We have identified the need to communicate across a number of boundaries, and wish to collect some empirical evidence related to practice and issues to address two research questions:

1. What are the communication and learning structures that facilitate transfer of knowledge and responsibility at innovation transition points?
2. What type of knowledge needs to be transmitted at innovation transition points and what structures facilitate this transfer?

As this is an exploratory study qualitative research was conducted as non-contrived comparative studies where the units of analysis were organisations. The study was cross-sectional and data was gathered from three case studies. The case studies were conducted in private and government organisations that had been involved in the research and development of technological innovations. The researchers were both embedded in the case study organisations in this research and while semi-structured interviews were used as a primary information gathering tool, table 2 outlines the respondents involved in data collected. The researchers also had access to documentation such as annual report, minutes of meetings and policy documents and direct observation record in research diaries provided additional data. This design was chosen so as to use the interviews and direct observations to provide exploratory and descriptive data within the case studies and give both breadth and depth to the data gathering. The sample of cases is a purposive as the three organisations used in this study were selected based on organisational attributes - that is all the case organisations were actively involved in innovation or their members were involved in the commercialisation of innovations. As such the organisations played a role in the transition of innovations to end-users. Only one attribute was a mandated selection criterion; organisations are all involved in the development of technological innovations.

A text based thematic analysis was performed on the data which applied an interpretive research protocol. The thematic analysis sought to identify structures such as workshops, presentations, documents and collaborations that facilitated knowledge transfer and identified the type of knowledge either technical(scientific) or operational(practice-based) that was critical for knowledge transfer. A cross case analysis, using Eisenhardt's[14] method, was performed in order to build theory and address the research objectives.

Case	Informants	Workshops
Beef Research Centre	5 Scientists 4 Extension officers 3 End-users	3 End-users 35 attendees 2 Researchers 25 attendees
Industry R&D Managers	47 Industry R&D managers, 12 academic observers, 18 government researchers	Six focus groups of about ten participants in each group
Australian Mining Company	7 research team members, 2 sponsor managers	Observation of 8 quarterly reviews (typically 9 attendees), 2 strategic planning workshops (15 people each)

Table 2. Respondents.

Case A "Poor Adopters"

Case A is a National Centre for Beef research and it is a well established, highly regarded Australian agricultural research and development organisation jointly funded by industry and government. It conducts research on DNA markers which are specific sequences of DNA that identify particular genes in an organism. In the beef industry, the commercialised markers show how many favourable copies of the gene an animal has for a particular production trait. For example, cattle have a number of genes that influence tenderness. One such gene is the Calpain gene. If the animal has two copies of the favourable form of this gene it has the genetic potential to produce more tender beef than an animal with one positive and one negative form of the gene. In turn, an animal with 1 copy of the positive form of the gene will have a better chance of producing tender beef than an animal with 0 copies of the favourable form of the gene.

The first DNA marker test was commercialised by an Australian company in 2000[15] allowing cattle producers to identify animals with the favourable genes by having hair, semen, blood or tissue samples tested. The results of the DNA marker analysis are sent to the producers in a report where the animal is ranked as 0, 1 or 2 stars for each gene (0 being no favourable forms of the gene and so on). The breeder then is able to select or mate cattle with a known genetic profile for that gene. The benefit of this over other selection methods is that it is a diagnostic tool, meaning that the specified DNA sequence is present or it is not and this does not change over the lifetime of the animal. This means that the animal can be tested at an early age and its future can determined prior to breeding, feeding or selling.

However DNA markers are complicated and hard to understand. A study by Moreland[12] suggested that intermediaries found the technology confusing This confusion in parts stems from poor knowledge transfer at the transition point where researchers transfer information to the intermediaries often this occurs after most of the development and proof of concept work has been done and is usually transferred in a lecture style presentation that sits the researcher rather that in a workshop style that would suit the intermediary. Similarly the process of collecting samples and receiving results is relatively easy, but the interpretation of results is complex and difficult. Moreland[12] also found that technologies were not always compatible with existing processes in businesses. So although the underlying science is reliable the technology has relatively low innovation fit. The confusion identified by Moreland or lack of understanding was reinforced in interviews and observations where Extension Officers from the Department of Primary Industries had difficulty explaining the science underpinning DNA markers. Extension Officers are key boundary spanning agent and utilise a range of practices and structures to transfer information concerning the potential benefits of innovations to businesses. The practices they use include workshops, presentations and field trips to businesses utilising the innovations. The practices usually involve technical experts facilitating the knowledge transfer activity. Many business owners preferred the field visits to sites where the innovation was being implemented as they could see the impact on the business and could ask the business owner about what changes they need to make to existing practices when implementing the innovation. While the extension officers have detail knowledge of business practices the technical experts rarely understand the impact of innovations on existing business practices and were often seen to downplay any changes to business practices that would be required, instead they focussed on the benefits of the innovation.

In other cases the extension officers were seen to promote the innovations that they were most comfortable with or the ones that were most closely aligned with their technical training. So an extension officer trained in pasture and crop management would be more likely to promote the benefits of improved pasture or cell grazing rather than improved genetics. This focus on discipline based information was not confined to extension officers. Scientist too tended to promote the innovations in their discipline area rather than take the view of which innovation was best for a particular business given its needs and resources. This relates to the type of information that needs to be transferred at the transition point involving the end user. The beef industry in Australia has two distinct production zones; a northern tropical zone and a more temperate southern zone. The cattle in the northern zone are tropical cattle and the cattle in southern zone are predominantly temperate European breeds, production practices and scale of operations in both regions vary considerable. So any knowledge transfer that occurs needs to be tailored to the production systems and any innovation must be suitable for the production system.

In Case A several scientists and researchers were strongly promoting the adoption of a set of practices that would produce tender meat to a standard. While meat produced to the standard was paid a production premium, in some cases the premium would not cover the costs associated with implementing the practices particularly in the northern tropical zone. In the northern zone businesses ran large herds and many exported live cattle so would not benefit from a production bonus. In other cases the businesses in the northern zone are located in remote areas often hundreds of kilometres from the nearest community or town. As a result of this isolation there was a critical shortage of labour and any innovation that required an increase in labour would be very difficult to implement. The practices associated with the implementation of the standard for tender meat would have necessitated an increase in the use of labour. This information was often not clearly transferred to the business owners, for example in one workshop an officer responsible for promoting the meat standard again focussed on the benefits and skirted some of the downsides, such as the need to minimise the use of dogs in mustering and the importance of not mixing herds of cattle in yards or on trucks before shipment to the slaughterhouse. In workshops it was left to the business owners to ensure they understood all the implications of implementing an innovation and for those business owners who did not fully comprehend the implications , because of poor information transfer or overly technical information or their lack of capacity to absorb all the information many business owners chose not to risk implementing innovations that were being promoted.

Case B: "Picking Winners"

Case B is an association of industry R&D managers focused on sharing best practice. In February 2009, a group of about 80 Australian corporate R&D managers met at an annual workshop/conference to share their experience in "picking winners". There were a number of presentations over two days of the conference, some related to people factors, and some related to matters of process. There were presenters from both large and small firms, and from private industry and government sectors. There was some discussion at the end of each presentation, and in the final afternoon of the conference, there were the focus group activities to reflect on what had been learned. A document capturing this information was produced a few weeks after the conference drawing on notes from various sources, and the original presentations.

It was clear that the expression, "picking winners" was very context-sensitive. One context for many of the participants related to identifying technologies that would enhance their enterprise's technology platform. For others, it was identifying which ideas for product innovation identified by the enterprise sales force should proceed to a development stage. For yet others it was identifying which newly developed products or processes should be given priority in the marketplace. Presenters from the investment community saw picking winners in terms of the probability of high rate of growth in sales in the marketplace.

A number of issues emerged. Firstly, having the right people to understand what was being considered and what progressing a particular innovation might lead to was seen as important. Secondly, having a process that considered a multiplicity of factors was important in conducting due diligence and information analysis that would support decision-making. Thirdly, clearly understanding the assessment criteria was important. For example, did the opportunity under review support some long term strategic agenda, in which case matters like relating to a current market might be a secondary consideration. Fourthly, having the right resources and capabilities to support an innovation during its development were just as important as selecting the best option to proceed with. Finally, it was noted that picking winners was a process, not a one-time event, and this process may have to be repeated at several stages during the development of a particular innovation.

Case C: "Proof of Concept"

Case C is an Australian mining company that generally undertakes significant levels of research into operational process optimisation rather than product development.In the early 2000's the Company decided to support the development of an aerial survey instrument based on about 10 years of research at an Australian university. The instrument is potentially capable of rapidly collecting information about the earth characteristics of a large region with a degree of precision many times better than that of current instruments. The researchers had developed a prototype to demonstrate what they called "proof of concept" in that the soundness of the underlying theory was demonstrated.

On this basis further engineering development of the instrument was funded. Some difficulties were experienced, in part due to the need to combine a number of emergent technologies in the design to achieve the desired outcome, and in part due to the initial adoption of inappropriate project management structures. Some components of the design were quite unique and difficult to make, and by the end of the engineering development phase, several patents have been lodged in addition to the original one. An iterative approach to project management was the norm. At this point, it was again declared that "proof of concept" had been demonstrated, in that it had been shown that a suitable instrument could be made.

This did not necessarily impress the geologists who wanted to utilize data collected using the instrument. To them, what had been provided at this point was the equivalent of a medical CAT scan instrument without any imaging software. In their view, "proof of concept" would occur once the instrument had collected data from a region with well-understood earth properties, and this data was presented in a form of map that could be interpreted in geological terms.

As in the "picking winners" case, there are matters related to the context of language in sense-making and to expectations associated with particular words or phrases. Again, implied meanings also relate to stages in the process of innovating. This case example also raises the matter of different mental models used by different professional communities. For the researchers, once the theoretical foundation has been established, further development work was not seen as problematic or risky, just plain hard work. For the engineers once something had been produced reliably, further development and application was not seen as problematic or risky, just plain hard work. For the users, an innovation is not regarded as adequately demonstrated until it has been shown through some period of use that it delivers a business outcome or solves a problem in a superior way to currently available alternatives. Even then, there is still work to do to extract maximum value out of this innovation.

Discussion and conclusion

The three cases presented collectively illustrate issues of communication and mutual understanding at different transition points in the evolution of an innovation and could be mapped on our communication matrix (Table1). In all cases, the presence of a diversity of agents - sponsors, people from various technical communities, project managers, end users were observed. There is a need to hand over prime responsibility within these families of agents from time to time. From this point of view, Table 1 could be expanded to include technological sub-functions of researcher, developer, tester and user. Management sub-functions of champion, project manager, investor, marketer and user could also be included. The task of identifying the generic role of each specialisation at each stage is significant in highlighting the complexity of communication involved, and will be a topic for further research.

In case B, a government research organisation described a strategy of developing prototypes and pilot plants, so that "proof of concept" could be clearly demonstrated. However, licensees were frequently disappointed in the extent of development reached compared with their interpretation of what "proof of concept" implied. The expression, "proof of concept" was also used by an industry presenter to mean that a product or process had been developed to the point where it was ready for trial in the marketplace. The expectation was that once "proof of concept" had been demonstrated, the innovation could be readily adopted. Similar observations were made in case C. The point case B reinforced is that both the language and expectations associated with transition points in the development of a particular innovation are important in reaching common understandings of the best way to move forward.

The purpose of the boundary-spanning activity is to help people learn what is needed about technological and management matters and to help access requisite assets for effective initiation of the next stage. This is illustrated in cases A and B, where picking winners was seen to be a process, not an event, and part of the job was setting up the right team for the next stage. In case C, concurrent engineering ideas were introduced to address boundary-spanning issues, and quarterly reviews involved all stakeholders. An external consultant developed a functional level systems engineering model of a total system in conjunction with all stakeholders which developed some shared understandings about the functional elements of the system, and to some extent provided a common language.

Going back to Giddens[4] structuration theory, structures of signification help produce meaning through interpretive schemas, communication and effective translation of overlapping language. This communication and translation describes the requirements of boundary spanning agent. We suggest that in a concurrent engineering environment, the primary transition focus is on technical schemas and language, but in the start-up business environment, the primary focus is on business/market schemas and language. At the transition points in innovation, processes knowledge is acquired, transferred and then in successful transition, integrated into the next phase of the process, consistent with the observations of Cohen and Levinthal[13]. As Kellog et al[8] argue boundary spanning agents are able to act as translators, brokers or mediators but this can only occur when they are able to access both sides of a transition point.

Our initial findings indicate that in innovation processes where boundary spanning agents are active the flow of knowledge and information is more effective than in those transitions where there are no boundary spanning agents. The findings also indicate that a common language is necessary but not sufficient for effective communication. There has to be agreed meaning associated with the language and the structures in place to facilitate such agreement.

This research demonstrates that the human element in innovation processes can both inhibit and contribute to the flow of knowledge. While innovation operates with a process framework, the flow of knowledge and understanding is controlled by and is dependent upon human interactions. As researchers we need to better understand the human elements involved in innovation if we are to make a significant contribution to theory. We suggest that discussion of nine communication regimes represented by the arrows in our communication matrix (Table1) can help reach common understanding of requisite communication flow within and between stages in the evolution of an innovation. While the case organisations described here are drawn only from Australia the findings may be applicable to wider audience. However further research is needed to validate the findings presented here in the areas of multi-agent roles and selection of appropriate next-stage management structures.

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