New Project Knowledge Management: Lessons Learned from temporary structures of Public Sector R&D Organisations

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Abstract.

R&D Organisations are key players in the knowledge economy and make major contributions to Australia's efforts to achieve and maintain competitive advantage. The explicit purpose of R&D organisations is to develop new knowledge and apply existing knowledge in new ways. Much of the R&D is carried out in temporary structures or project teams. Drawing upon theory and grounded in case based evidence, this paper explores how new forms of project management affect knowledge generating and application processes in R&D organisations. It appears that much of the knowledge generation and application occurs through taking advantage of almost naturally occurring oscillations between open and closed system practices over the course of projects. Theoretical and practical lessons and implications for further research are advanced.

Introduction

Public Sector R&D Organisations are key players in the knowledge economy and make major contributions to Australia's efforts to achieve and maintain competitive advantage by developing new knowledge and applying existing knowledge in new ways for the public good. This does not mean that such research is necessarily free, on the contrary most western societies have moved to the adoption of commercial practices, as a means of addressing market failure. The creation of knowledge involves individuals, and groups or teams working together in environments which encourage and sponsor innovation. Much of the work undertaken by R&D Public Sector organisations can be examined through the lens of temporary structures or projects. Specifically we examine how new forms of project management affect knowledge generating processes in Public Sector R&D organisations.

Worldwide, a decline in government funding for R&D is the main reason why public sector research organisations are seeking commercial partners and multiple funders, and adopting marketing and end-user involvement strategies to minimise market failure in their quest to maximise public good (Papageorgiou, 1993; Eisenberg, 1996; Massaro, 1996). Many of these R&D practices are being borrowed and modified from the third, fourth and fifth generation R&D models that have been developed in the private sector (MacLeod & Shulman, 1998; Liyanage, Greenfield & Don, 1999). As most R&D in the public sector was done without much involvement with persons other than those within the research unit, this has been a major shift for most public sector research organisations, and one that is accelerating. The involvement of these different constituents who are often geographically separated, and the need to manage these relationships, in many ways makes these projects "temporary organisations".

On the one hand, such conditions of multiple input, from multiple players are perfect conditions for increasing the potential for generating new knowledge in a manner that knowledge will become shared by those taking part in the dialogue, and for innovation to emerge. On the other hand such conditions can lead to disorganisation and inefficiencies. The challenge is to manage this temporary structure so that knowledge creation is likely to occur, but in an efficient manner, and for knowledge gained within this project to be accessible after the project is completed or abandoned.

But how we can simultaneously/sequentially manage open versus closed temporary structures so that they stimulate knowledge development and utilisation? In this paper we integrate theory with case based evidence to suggest how this might be done. It builds on some recent theorising by Nicherson and Zenger (1998) that suggest in uncertain environments, oscillation between closed and open systems organisations has distinct strategic advantages. We suggest that those project that are managed to take advantage of these oscillations, rather than always trying to minimise them, are more likely to minimise market failure. Current project management practices (portfolio management, as just at the last moment, reviewable milestones, multiple site visitations) and concepts like sticky knowledge (von Hippel, 1994) are congruent with this, and if recognised and amplified, can create optimal conditions for adaptive learning systems to be advanced.

This paper examines knowledge processes in R&D Management, initially in terms of the emerging models of R&D management and then as stocks and flows, followed by the findings of new project management. We then describe the oscillation of open and closed systems at the project level, using extracts from interviews with R&D project leaders in public sector agriculture**.** Our data was collected through interviews, observations and archival records over a two-year period. This collection occurred at the project, program portfolio and organisational levels within two industry Research and Development Institutes recently created under a purchaser-provider policy by a State Government. Lessons learned from our investigations and implications for future research are then addressed.

Knowledge Management in R&D Management

R& D Management has been described using either market based or science push approaches, where both are linear approaches. However, the great challenge is in linking emerging technologies with emerging markets, and the model of innovation required is, “Not technology push or market pull, but how tight is the evolutionary loop? ”(Brown, 1997).

Models of R&D management have evolved from linear models to process models of managing an arena of players, and moving from closed systems to open systems approaches; from R&D simple linear transfer of technology approaches where specialists operated independently of each other and often independently of outside clients to increased dialogic practices with market pull and science push. These models of R&D are summarised in Table1.

Table 1: R & D Project and portfolio communication management models

MODELS OF R&D	DISTINGUISHING FEATURES
First Generation	Linear Transfer of Technology (TOT), where R&D specialists operate independently of other extension & marketing staff and from potential clients from outside agencies. Followers of these practices have had limited success in improving outcome performance
Second Generation	Increased dialogue at the formulation stage concerning aims of specific R&D projects, both science-push & market-pull; seek interactive dialogue between R&D providers & clients. Limited success.
Third Generation	Recognised need for partnerships between public R&D providers and clients & commercial businesses. 3 key features: portfolios of projects are used to spread risk, unnecessary tight coupling is to be avoided particularly in the research phase, and the need for mutual trust between parties and acceptance of unique contribution to RD& E process is recognised. This has emerged as the dominant 1990's model.
Fourth Generation	Recognition of the political nature of R&D. RD&C is a dynamic process with resolution of conflicting interests changing alliances and competing world views. Major understanding of the rules for managing appropriate expectations within the partnerships and alliances.
Fifth Generation	Arena theory: composition, predisposition and relative power of different stakeholders will shape the range of possible inputs, outputs and outcomes. The knowledge generation capacity and the political nature of constituents are to be conjointly managed. Hence, choice and timing of involvement of stakeholders is critical for optimising innovation and delivering on its potential.

Source: Adapted from MacLeod & Shulman (1998).

Each of these models progressively builds on the previous one. The current fifth generation model acknowledges that R&D exists within a multi-layered network of relationships, where the value adding performance of R&D depends to a large extent on the performance of other actors to which it is directly and indirectly connected. Knowledge is developed through social-political processes and the social production of knowledge and the effectiveness of individuals and their functioning within a social context. Knowledge can be considered less as a product that as an aspect of practice.

Knowledge can be thought of as stocks and flows, where knowledge is embedded in capital such as technology and production systems, in social and organisational systems, such as norms and practices and in individuals. This embeddedness of knowledge takes different forms in organisations. For example *capital-embedded knowledge* such as technology, tools and machines; *institution-embedded knowledge*, the rules and roles and traditionally closely related to culture, notion of identity; *organisation-embedded knowledge,* knowledge that is embedded in the work organisation, to be able to influence the logistics of internal and external operations and

*individual-embedded knowledge, w*here individuals exist in a knowledge context (Ekstedt et al. 1999). This is consistent with the work of Spender (1994), much of workplace knowledge is collective knowledge that is embedded in social activity in ways that is relatively hidden from the individual social actors (Spender 1994: 396). This collective knowledge is a dynamic concept which is not only held collectively, but also generated and applied collectively within a pattern of social relationships (Spender, 1994: 397).

Knowledge as flows is important and the 'transfer' of knowledge within units and across units of a company plays a crucial role in knowledge generation and the spread of ideas and technologies. Relationships between knowledge partners appear to play an important role in mediating the knowledge sharing process. Recent work on knowledge transfer has focused on networks and collaborative ventures (Inkpen & Dinur, 1998) investigated the transfer of knowledge in an alliance. Collaborative relationships with stakeholders are of prime importance in R&D (Rothwell, 1994: Macleod & Shulman, 1998). Rothwell (1994) explicitly mentioned the use of horizontal linkages, collaborative, competitive and networking processes in R&D processes, and Macleod & Shulman (1998) discuss 'collaborative network restructuring to promote flexibility in dynamic environments'.

Organisations are not unitary and can also be seen as diverse communities (Schein, 1996) or constellations of communities. They are also networks of knowledge, where some information is regularly shared. Organisations may address these challenges by allocating a large portion of their information-processing activities outside their formal boundaries, by adopting novel socialisation tactics, and by focusing on the management of soft knowledge (tacit knowledge, judgment and intuitive abilities) (Anand, Manz & Glick, 1998). Researchers in the R&D Organisation of XEROX PARC suggest that an organisation's innovative advantage lies in its ability to manage the flow of knowledge across its constituent communities (Brown & Duigood, 1999). Similarly the flow of knowledge within R&D projects is shaped by the knowledge brought to the project by the constituents**.** Who these constituents are, and how they are encouraged and discouraged to be involved in the knowledge creating arena can change the availability of intellectual capital and the social capital that can in turn, change the probability of specific processes being engaged in and the specific outputs and outcomes of the enterprise. (It is not only the actual input of others that can shift decisions, but also the anticipation of their availability as well as their prior association that can shift the emergence of alternative actions that are considered).

New project management as temporary structures

Traditionally project management has taken a prescriptive view of the procedures required for product or process development. Project management tools, as PERT, and practices of tight specification of products at the beginning of the project, continue to predominant These are scaled downed versions of the engineering/logistic practices put into place to coordinate workflow for large scale military and construction projects. Recent surveys of the success rates of R&D projects using these tools have suggested that up to 95% of them required major deviation from the linear prescriptive approach, in part because the original specifications were wrong and needed to be iteratively revised. New strategies are required for innovative projects and situations with more multidisciplinary interests and concern with new markets and scientific

explorations. The new approaches to project management such as concurrent project management are currently being implemented in companies to meet the demands for new products, services and 'speed to market', challenge prior practices of standardised normative views of project management.

New Project management can be described as neither open nor closed but oscillating, with alternative loose and tight and tight relationships. With an uncertain environment, it is best to maintain oscillation, where continual fluctuation builds flexibility to meet unexpected changes so that people can move in and out strategically. Managing relationships in R&D constitutes management of paradoxes. Literature dealing with new project management in the manufacturing sector has found what is commonly referred to as the overlap paradox: ie. longer involvement is required for shorter projects. The processes involve the development of anticipation, the formation of a multi-functional team, and the maximum postponement of moment at which highly irreversible choices are made; ensuring overlap between various project contributions for hand over from design to production and all involved are ready to act if problems occur at product launch. Other changes identified in the manufacturing sector include, moving:

- From stable contractualised context to an uncertain and flexible work environment
- From sequential autonomous contributions to interdependent collective processes, with interdependence of contributions of various participants. Here the goal is to find the best overall compromise and encourage dialogue and mutual adjustments
- From work based on specialist expertise to dedicated assignment of individuals, which emphasises the importance of continuity in project teams. The permanent presence allows for the formation of project memory for decisions taken, directions chosen and ways forward looked at and abandoned. The precondition for management founded on responsibility for results requires that the same people drawing up projections have responsibility for achieving them. Individuals are assigned to take charge of all the project issues for the duration of the project (Charue-Duboc & Miller, 1999: 171).

RD&E in Agricultural Research

Agricultural research involves research, development and extension, where extension is the name given to the dissemination of the results of research in agricultural research. Instead of being an add-on after the innovation has occurred, end users (growers, storage handlers, machinery makers or industry organisations) are active partners in the design and implementation of R&D. The extension process is largely integrated into the R&D at every stage of the process, creating an arena of players who are involved early in the project and who play important roles through the life of the project.

R&D projects in agriculture are strongly related to contextual factors or project embeddedness that affect the project organisation throughout the whole project. Organisations are embedded in a complex societal web of people resources, institutions, market conditions, and the activities inside them are always affected by the characteristics of that web (Granovetter, 1985: 37).

Patterns that emerged from our research include the simultaneous engagement in open versus closed systems and loose versus tight coupling of activity links. The following extracts from

interviews with experienced R&D project leaders illustrate these patterns. The first set of extracts illustrate an open system with attempts to retain possibilities of equifinality and capitalise on serendipity, but in a context of a planned closed system. RD&E project leaders build flexibility into their proposals to maximise their ability to respond to emerging findings.

> When I wrote this particular project, I deliberately wrote it so that there was some flexibility, because some of what we're doing is unknown. There's no point doing research if you know the outcome basically. So I wrote the project in terms of giving myself and my staff a bit of latitude to take a couple of different directions if we needed to.

They also use multiple locations to generate knowledge. As illustrated below this is consistent with von Hippel (1994) 's work. His work illustrates that where more than one site for relevant information exists, (and different knowledge bases reside in different groups) the locus of the problem is likely to shift back and forth providing alternative ways of addressing the problem.

> The project is called "Strategies for Management of [Plant Disease]", so we're investigating different strategies. We don't know what the final package of recommendations will be, but what we're trying to do is test as many things as we've got time and money to test and at the end of this project, deliver to industry a package of recommendations appropriate for different locations, appropriate for different situations, appropriate for different races of this disease. So we'd be very much focused on a practical package at the end. But what that's going to end up being, I'm not sure.

Flexibility of milestones is also required in research relating to biological systems which underpin agricultural RD&E.

> Some people only do what they set out to do in the milestones, but I have never worked like that. So all mine are so flexible. My point is that we are not doing copycat research, you really don't know the result, so we have a lot of flexibility built in with our projects, because we don't know what direction we're going to go in. Now, sometimes it's difficult to meet your milestones, but you shouldn't have too many milestones and they should be simple, and then change them. With the avocadoes, we suddenly changed direction into another field, into this root stock interactions, chemical analysis, anti-fungal, we didn't even have that in there at the start.

Interestingly, at least one Australian research and development corporation (LWRDC) has recognised that their use of milestones needed to be reconsidered. They now state that specific targets must be specified, but at the same time they explicitly state that they expect that most, if not all, will need to be modified to deal with the unexpected. That changes in milestones are expected, but must be justified. (LWRDC Management newsletter #1, 1999)

R&D projects find useful results which lead in new directions, which could not have been predicted prior to some of the testing or trails being carried out.

> They wanted a better spray program for avocados to control a major fruit disease. So we had these new generation chemicals, plus we had defence promoters and things like that, that we put on to see if anything would work. We found something there that worked but, in the meantime, we found another interaction, so a lot of our research has gone in that direction which wasn't even in the first project. Now a lot of researchers will say, that's not in this project, we won't touch it. But I've never worked that way.

The next set of excerpts illustrate how R&D project leaders respond to new needs by extending their projects to involve essential areas of expertise, external to their organisation. Managing people across a range of organisational boundaries is easier when RD&E project leaders have autonomy in managing their projects to deal with emerging requirements.

> For example, the person who's come in recently, is a plant pathologist. The reason he's come in is because we have a new disease in sorghum, it was identified a couple of years ago. So there was a need there. There was an issue. And we needed to attack that and work on that issue. And we needed a team of people which included a plant pathologist who wasn't in the program before. So we basically rang each other up. And that happened at the scientist level, rather than being imposed on us by management.

R&D project leaders engage in a range of practices to maximise the effectiveness of their projects. These practices ensure strong linkages with the end users of their work, such as the growers and industry associations as well as the R&D funding organisations.

> In terms of dealing with the grower groups and if you've got strong linkages with the growers and they have an input into developing a project proposal, then again, I think you have to go with the flow. In our original citrus proposal, we were going to do an assessment of four varieties of one off assessment and when we did the first assessment, the results from the first variety trial weren't quite as good as we'd hoped. So I put it to the industry group at a meeting in the Central Burnett that we could do an additional trial the next year and we'd actually improve the baiting and everything and they took a vote on the day, and said yes, we support that and we'll give the extra money, we want that extra trial done. Now that wasn't part of the original plan, so I think in that sense, industry will be flexible if you are giving them what they're paying for.

The strong linkages with the grower groups throughout the project allow the openness and flexibility of response that are required in ongoing work. However the strong linkages between the researchers and the end users may also prevent the inclusion of new ideas from other groups creating a closed system with a sole provider. The dimensions of open and closed systems may have different purposes in the life of the R&D projects. Different amounts of diversity may be required for particular purposes. For example the best

opportunities to attract more funds may required a closed system such as stating what you will do, and how you will do it, when in fact their research is to find out the process, whereas best practices in research may require more open systems. The balance and the timing of open and closed system practices need to be taken into account in the generation of knowledge.

The closeness of the relationship with industry often leads to insights, later developed in framing proposals for new projects, ownership of the results of the research and often partnership in particular projects.

> I talk to the industry and they say they are happy to go in that direction. That's what research is all about, it's discovering something new. And industry will allow you to do that.

Agreements to work with others, say on retainer, or to share equipment on an 'as needs' basis also provides an 'open" system to manage the unspecifiable. Partnerships are also developed with other research institutions, cooperating with other scientists to use resources not available within the organisation. Often these relationships are recurrent.

> We're working on a particular attribute, which has the potential to improve the feed grain quality and we needed animal people to work with us on that. And for some reason or other, we hooked up with a group at Ewingwood University. And from that, this sort of work is now in a GRDC (R&D corporation) project, a premium feed grain program, and that group now is in there. So we saw the need to increase the feed grain quality. We could handle the genetics of it and we needed partners. Once again, we mutually saw the need for cooperation.

Co development teams are also used to develop and test alternative strategies for meeting an objective. These are best used when there is an urgency and/or high investment in the best ways of proceeding. Having the teams work in parallel and exchanging their findings have allowed for the delay of resource decisions until the alternative ways are tested. This is consistent with management at the last moment and keeping options open. Or as is illustrated below, occurs when decisions are delayed until insights from a parallel project are available.

> I guess that does happen to a certain extent with the some of the fusarium wilt of banana research and some of the fusarium wilt of cotton. There's a pathologist on the banana project who's looking at certain things, which I'm not going to bother looking at in the cotton, because I'll wait and see what comes out of that. The best of those, we'll apply to the cotton and vice versa. There's an experimentalist on the cotton projects who's looking at certain things that may have an application for banana and I won't be duplicating them in bananas. So I guess, in that way, it happens. It's good and those two people get on very well too and there's been a lot of good sharing. I guess I didn't formally set that up within one project. That's just two parallel projects I suppose and parts of those projects are related.

> That's happened by chance. I was working exclusively on a particular disease in banana until Australia's first outbreak of this disease in cotton occurred. And then our help was needed because we had worked out how to identify the pathogen and how to differentiate the different races or the different strains. So we just applied that technology to the cotton situation and my position became half time on those and then we got projects under both of those, and that's how it happened. So I didn't deliberately set that up.

Not all the tools and practices used by these project leaders were intended to maximise openness. On the contrary, many were used to close down alternative approaches and get the project completed. These included subcontracting for specific work to be done in a specific way at a specific time.

> I do have third party contracts with two of my projects though, but they were written into the project straight away. That's for somebody at UQ to do some molecular work and somebody at NSW Agriculture in Gosford to do some post harvest work. But the project was negotiated with them right from the start.

> We have a team and within our team we make sure every aspect is covered. We don't have to subcontract anything out. Perhaps we do. Now that soil analysis is in a different government department, they do analyses for us and we have to pay and we have to subcontract some other things, analyses to the University of Queensland. But they're only functions that we can't fill within our team. If we want additional work done outside of the skills of our team, yes, we go outside and subcontract the research.

In our observations, in every single project there were practices which resemble both closed and open systems. There is a tendency for project proposals to be formalised as if the processes and procedures for getting to a particular outcome are known, ie. at the extreme, that the unknowns were not really unknown. In practice, the researchers are managing a large number of unknowns and bringing in other stakeholders into the arena. In some ways they are presenting the process as closed either to close off those audiences or to meet the prescribed requirements of funding organisations.

Patterns of open and closed systems which emerged from our study of R&D projects with applied research can be compared to similar patterns of relationships found at other levels within research organisations. They may also be applicable at different levels of the organisation, where the oscillation of open and closed systems affects the R&D at the project level but also at the portfolio level, and at the strategic level of R&D management. For example in the past, research carried out in academic organisations such as universities tended to have fluid boundaries, where the partners or collaborators have few restrictions on their processes. In contrast, commercial organisations tend to produce all of their R&D within tight boundaries of their organisations or form strategic alliances or joint ventures with other firms, usually entering into formal contracts. The movement over time has been for the group with open systems, traditionally universities, to move to more fluid oscillating relationships with constraints introduced from intellectual

property, while the more closed system of commercial partnerships has moved to ongoing windows of openness.

Lessons learned from new project management processes

New project management offers new perspectives on ways of generating learning or knowledge formation. The processes previously identified in new project management in manufacturing are also found in public sector R&D projects in agriculture. These include the oscillation of open and closed system practices over the course of a project.

As obvious and ubiquitous as this is, little research has been directed at understanding how, over the course of a project, program or the life of a board or other organisational unit, changes in the composition of constituents within the stream of meetings/activities that constitute project management matters. Research that has been done has focused on internal arrangements particularly between design and production departments in manufacturing. A procedure that we have used in earlier phases of this program, points out this iteration.

Other practices of moving from a stable contractualised context to an uncertain and flexible work environment, moving from sequential autonomous contributions to interdependent collective processes, with interdependence of contributions of various participants, and moving from work based on specialist expertise to the dedicated assignment of individuals and the importance of continuity in project teams are also observed. The continuity of project leaders on each project as well as in a program of related research is similar. The precondition for R&D management is similar to manufacturing, founded on responsibility for results; where the same people drawing up the projections have the responsibility for achieving them.

Discussion and Conclusions

R&D projects can be conceptualised as temporary structures or temporary organisations. The development of knowledge management practices in R&D is reflected in the movement towards fifth generation R&D models, where the arena with multiple players in a dynamic environment shapes the range of possible inputs, outputs and outcomes. We found evidence of new project management processes previously articulated in the manufacturing industry as well as the individual embedded nature of the knowledge in temporary organisations, enhanced by the richness of the arena and the continuity of the project leader's involvement with their partners in the challenge of RD&E. However, our analyses suggest that traditional prescriptive models of project knowledge management fail to capture the observed simultaneous engagement in open versus closed systems and loose versus tight coupling of activity links. Nor do they capture the observed ongoing oscillation of open and closed system practices over the course of a project. In addition to the overlap paradox that increased time leads to efficiency and effectiveness, we argue that recognising that systems are simultaneously open and closed may lead to increased efficiency and effectiveness.

Implications and Future Research

R&D projects as temporary structures, are ideal situations to examine best practice for managing knowledge creation and utilisation. Our research illustrates that R&D practices are often simultaneously and iteratively open and closed, with much of the fluctuation emerging around the bringing in and out of constituents. Our research efforts have yet to capture the ways in which these systems interact and overlay one another. And this will need to occur if we are to build a coherent picture of these learning organisations. Further research is also needed to address if and when explicit recognition of the management of the arena as an oscillating open and closed system will effect project behaviour and maximise effectiveness.

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