Working around the barriers to creating and sharing knowledge in capital goods projects: the client’s perspective


C. J. Ivory
University of Newcastle upon Tyne Business School, University of Newcastle-upon-Tyne, UK

N. Alderman
University of Newcastle upon Tyne Business School, University of Newcastle-upon-Tyne, UK

A.T. Thwaites
Centre for Urban and Regional Development Studies, University of Newcastle-upon-Tyne, UK

I. P. McLoughlin
University of Newcastle upon Tyne Business School, University of Newcastle-upon-Tyne, UK

R. Vaughan
University of Newcastle upon Tyne Business School, University of Newcastle-upon-Tyne, UK

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The paper considers knowledge management issues from the client’s perspective. In the example presented, a sludge treatment centre procured by Northumbrian Water Ltd (NWL), the task faced by the client was to manage knowledge in a context where the core technology being procured was new and resulted in the need for new knowledge to be created and shared both pre- and post-delivery. In exploring these issues, the paper reveals the problems of (and some solutions to) managing knowledge across the project life-cycle and between different groups, where the motivation for generating and sharing knowledge was not the same for all participants.

Key words: knowledge management, learning, technology adoption, capital goods projects.
Introduction

The paper considers the knowledge management problems facing clients who are procuring complex capital goods\(^1\). In the example presented, a sludge treatment centre procured by Northumbrian Water Ltd (NWL), the task faced by the client was to manage knowledge in a context where the core technology being procured was unfamiliar. In contrast to much of the literature on knowledge management in the capital goods project context, this paper takes the perspective of the client and considers the means by which the client has generated, managed and embedded the knowledge it required from its supply chain. The paper shows, however, that in complex multi-organisational and fragmented contexts like capital goods projects, where sharing knowledge across organisational and inter-organisational boundaries is essential, the motivation of different groups to do so can be unevenly distributed across the structure and temporal span of the project. The paper also reports on some of the ways in which the client, motivated by the need to generate and embed new knowledge from its suppliers and its own internal operations, acted to re-configure some of the interactions and motivations within the project to encourage the generation and availability of new knowledge where it was needed.

Knowledge management and organisational learning

Knowledge management is increasingly viewed as key to competitive success for the organisation (Easterby-Smith et al., 2000). Knowledge and its proper management are now regarded, moreover, as essential for firm survival in increasingly turbulent and competitive environments (Davenport and Prusack, 1998; Easterby-Smith, et al. 2000; De Long and Seemann, 2000; Brown and Duguid, 1991) and knowledge is viewed as critical to ensuring that new products and services can be created and improved (Hamel and Prahalad, 1994; Teece and Pisano, 1994; Robertson, et al., 2003). As Howells (1996) notes, “...it has become increasingly acknowledged that the contribution of technological innovation to growth and economic performance is not just simply associated with embodied technologies, such as new plant and equipment, but is also highly dependent on disembodied, intangible assets and working practices” (p. 91).

Theories of knowledge have, therefore, set down deep roots in management theory and practice. Organisations have come to be conceived of as 'systems of knowledge' (Blackler and Crump, 2000) and as 'knowledge-based systems' (Tsoukas, 1996). Organisations have also come to be seen as sites of 'situated learning' (Fox, 2000) and as comprised of

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\(^1\) A capital good is a physical artefact which forms part of the operations of the client organisation in which it is embedded. Capital goods may include, therefore, such artefacts as buildings, IT systems, manufacturing process machinery, weapons systems, trains, ships and aircraft.
'communities of practice' with their own knowledge and embedded practices (Lave and Wenger, 1991). Interest in organisational learning, knowledge creation and knowledge management within projects is a more recent phenomenon and one that has received less attention (van Donk and Riezebos, 2004; Fernie, et al., 2003). Nevertheless, here also, organisational learning and knowledge management is coming to be seen as a crucial component of both successful project-based firms and projects. Knowledge management is seen as critical for contracting firms to capture learning that will improve their 'front-end' processes of bid preparation and planning (Davies and Brady, 2000) and in ensuring the sharing of knowledge within and across projects and project-based organisations (Gann and Salter, 2000; Prencipe and Tell, 2001; Ruuska and Vartiainen, 2005). Good knowledge management is also seen to lie at the heart of innovation in the capital goods industries through, for example, encouraging the development of tacit knowledge for problem solving (Barlow, 2000) and contributing to the ability of projects to meet their clients’ needs (Alderman et al., 2003). Critically, the temporary 'project team' is increasingly seen as the focal point for learning (Barlow, 2000).

As the subject has been populated by social and organisational theorists, approaches to knowledge and knowledge management have become increasingly distanced from their 'rationalist' roots. The 'rationalist' approach to knowledge management regards knowledge as a commodity (Whitley, 2000) and as an asset (Marshall and Sapsed, 2000), capable of being acquired and deployed like other material resources. As such, this approach, where it does see problems to be solved, sees them in terms of systems to ensure the codification and circulation of knowledge (Bresnen et al., 2003). The rational view of knowledge, however, has been increasingly criticised from the perspective of a model which views all knowledge as, at least in part, tacit (e.g. Hislop, 2002); a perspective that treats knowledge as people-centred and is dominant in social science discourses (Alvesson and Karreman, 2001). In this model, knowledge cannot be viewed as a 'commodity' or tangible 'thing', but must be seen as an interactive process tied inexorably to the context of its production (Bresnen, et al., 2003). Moreover, this tacit aspect of knowledge, 'knowing', can only properly be developed through the 'conscious effort' (Howells, 1996). Moreover, 'learning by doing', 'learning by using', 'learning to learn' and 'trial and error', all of which are crucial elements of developing this knowledge, require direct on-the-job experience of machines, work practice and operations (Howells, 1996). It follows, therefore, that a proportion of the knowledge that is critical to effective operations is not merely an object that is 'captured', 'stored' and 'transferred', but rather it is part of a process involving action (Blackler, 1993) and practice (Brown and Duguid, 1999). Thus, we see the management of knowledge as necessarily 'close-in' and as cognisant of the practical issues facing individuals in the context of their work (e.g. unexpected technical problems, cross-boundary politics and so on). Our focus in this paper is, therefore, less on knowledge management 'systems' (in the

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2 This view has been seized upon and reinforced by Information Technology system builders (Easterby-Smith, et al.2000). The 'IT' view of knowledge, in keeping with its rationalist roots, rests upon, and reinforces, the increasingly outmoded view that organizations are unitary, mechanistic systems (Tsoukas and Cummings, 1997).
formal or technical sense), as on management practice in the context of complex capital goods procurement.

Creating and sharing knowledge within and across organisations

For the purposes of this paper, work on knowledge management has been subdivided into three broad and overlapping categories: communities (those approaches which stress the role of social groupings in knowledge production); organisational context (those approaches which stress the embedded nature of knowledge and its dependence on the context of its production); and networks (those approaches which stress the importance of the flow of knowledge). These categories are by no means exclusive and many authors draw upon more than one. However they form a useful way of organising thinking about key issues in knowledge management, particularly in the context of capital goods projects\(^3\). These categories are discussed in more detail below.

Communities

The community approach to knowledge is rooted in the sociology of knowledge (e.g. Kuhn, 1970, Berger and Luckman, 1979) and ‘communities of practice’ (Lave and Wenger, 1991; Brown and Duguid, 1991). Together these approaches stress the importance of the shared practice, mental models, language, systems of meaning and schemas held by individuals in a given community. These practices, mental models, schemas, languages and systems of meaning are taken to develop, through interaction, in conjunction with other members of that community. Thus, for example, 'understanding', and therein the co-production of knowledge, is seen to occur through 'narration' and 'shared work' (Bresnen, et al., 2003) in the context of institutionally-shaped ‘ways of doing’ (Robertson et al., 2003). A closely related approach, the ‘activity systems' approach (Blackler, 1993; Blackler et al., 1998) makes a similar claim. The creation and exchange of knowledge is also seen by this approach as an activity bounded by a particular social group. ‘Activity systems', argue Blackler et al. (1998), comprise the social, linguistic and material practices which make 'knowing' possible. Within activity systems, interaction (and so the production and exchange of knowledge) is mediated by tradition, rules, divisions of labour and so forth. The goals and objectives which guide knowledge production are themselves also constrained by the culture, roles and technologies defined by the activity system (Blackler, 1993). These systems assimilate newcomers through socialisation and themselves also evolve over time (i.e. they learn from past experience). They are, in other words, self-reproducing and rooted in their own history. Lave and Wenger (1991) make a similar point about the development of

\(^3\) Capital goods projects involve a number of different communities (e.g. consultants, contractors, materials and technology suppliers). Each project will also comprise a particular organisational context in terms of a particular structure and culture. A project can be, for instance, more or less adversarial depending on the contract conditions determined by the client. Capital goods projects are also comprised of networks in the form of extended supply chains and other inter-organisational and personal networks.
communities through apprenticeship. This, however, can make such systems resistant to change and, moreover, unintelligible to 'outsiders'.

Communities and 'activity systems' have critical implications for knowledge transfer which are largely ignored or down-played by traditional approaches to knowledge management. Because knowledge is tied up in the specific language practices of particular communities, its externalisation does not necessarily then make it available to other, different, communities (Bresnen et al., 2003).

**Organisational Context**

Organisational culture, routines and management practices are also viewed as essential to the facilitation of knowledge-sharing in the people-centred-approach. These affect communication flows, organisational roles and, by implication, information sharing (McGill and Slocum, 1994). There has been an increasing interest, for example, in the conditions in which tacit experience-based knowledge is best externalised by individuals and made available for others to use (Nonaka and Takeuchi, 1995, Nonaka and Konno, 1998). Although Information Technology is seen as a knowledge exchange enabler (Nonaka and Konno, 1998), social context is nevertheless recognised by these authors as a critical and 'enabling condition' for sharing knowledge. For example, environments which are emotionally supportive (Nonaka and Konno, 1998), or which support experimentation and reward innovation (Dougherty and Hardy, 1996), are seen as critical to knowledge creation. Similarly, trust is seen as critical to knowledge sharing; the presence of trust results in a reduction of opportunistic behaviour with regards to knowledge and this makes knowledge exchange possible (Heumer et al., 1998, Howells, 1996). Therefore, organisational cultures that support the development of interpersonal trust also appear to support knowledge sharing.

Loose organisational structures are also seen as supportive of knowledge creation and exchange (Ravasi and Verona, 2001). Roles and authority should be relatively ambiguous (in their words 'loosely coupled') to allow dialogue and the "creative combination and recombination of individual and organisational knowledge" (p.43). Conversely, they suggest, tight coupling can reduce creativity (i.e. knowledge may be shared but it may be highly conservative). A preoccupation with measurement (and punishment) may also, they suggest, create a functional environment that will hamper creativity and collaboration, while overly formal structures can trap and hide knowledge within organisations.

**Networks**

Knowledge-exchanging networks form both within and between organisations and constitute the backbone of the communications system by which knowledge is shared and co-developed. Collaborative networks between firms are often central to the development of new technologies (James and Howells, 2000; Semilies, 1999) and in particular complex technologies (Molina, 1989, 1993; Miller et al., 1995). Networks with other organisations often constitute the source of new market and technical knowledge, for
example from users (e.g., von Hippel, 1988) or suppliers (e.g., Gann, 2000). Knowledge exchange through collaboration means that an organisation can overcome, to a large extent, the slow processes of internal learning (Grant, 1997) and that they can gain access to technological knowledge and competencies beyond their own knowledge boundaries (Tidd et al., 1997). Firms are also able to make greater use of the knowledge they already hold by collaborating (Grant, 1997; Shapiro, 1999).

As within organisations, knowledge is also best built and shared between organisations through close-knit trust-based networks (Bresnen et al., 2003; Larsson et al., 1998). Networks may constitute trust-based communities, such as the architectural profession (Symes et al., 1995), or suppliers of similar specialist products in a small industry where knowledge-sharing is the norm even between potential competitors (e.g., suppliers of specialist components to complex products such as flight simulators, Miller et al., 1995) or where supplier knowledge is essential to support client adoption (Grant and Gregory, 1997; Grant et al., 1991 Chai, et al. 2003; Bohn, 1994).

Knowledge transfer can occur through a number of means: the transfer of equipment, documentation, know-how that has been documented in ‘black books’⁴, formal training by knowledgeable staff (e.g. from the supplier), on-the-job training and site visits to the supplying organisation (Grant and Gregory, 1997). Chai et al.’s summary of the knowledge transfer literature also identifies inter-organisational teams, boundary spanners, best practice guides and procedures, internal conferences and staff transfer. As they point out, however, different types of knowledge and knowledge requirements require different sorts of transfer mechanism. With respect to technology transfer they divide knowledge into knowledge for the purposes of creating awareness and for the development of skills once the technology has been adopted. Awareness, Chai et al. argue, can be served by boundary spanners, internal conferences and meetings, audits and periodicals whereas the knowledge required to develop skills and processes that will support the technology once adopted requires a more intense interaction, such as that provided by detailed reports, periodicals, best practice guides, benchmarking visits, staff transfer and training of staff by the technology supplier.

It follows, however, that successful (technology-related) knowledge transfer will depend greatly on the adopting firm’s own internal capabilities to absorb knowledge (Cohen and Levinthal, 1990; Grant et al., 1991). Important, therefore, are the skills, experience and education levels of the workforce and the degree to which senior management are prepared to bring about the organisational changes that are often necessary to properly embed a major capital good within an organisation (Grant et al., 1991).

Networks through which knowledge can transfer may also be formal or informal (Conway, 2000). Informal networks, claims Conway, are key in knowledge diffusion.

⁴ These are an attempt to document the ‘know how’ present in the heads of existing operators (Grant and Gregory, 1997).
They fill in the gaps left by formal organisational structures (see also Dougherty and Hardy, 1996) and perform important boundary-spanning activities between otherwise unconnected sources of knowledge within the organisation. However, such networks can also be corrosive in that they can form goals that contradict those of the formal organisation. They may also be the cause of the loss of competitive knowledge to other organisations such as customers or partners who may then go on to become competitors (Boisot, 1995).

**Summary**

It is clear from the literature that the creation and distribution of new knowledge is dependent upon a complex mix of factors. Knowledge needs the right environment for its creation. Staff must exist in an organisational culture which supports and values creativity and knowledge sharing. Having achieved the creation of knowledge, its distribution still faces, it is suggested, considerable barriers. Codified knowledge travels all too easily into the hands of competitors (Boisot, 1995) but not so tacit knowledge. Close contact in a common working environment and suitable network conduits are necessary, but not necessarily sufficient, for tacit knowledge transfer between groups. A strong case is made in the literature reviewed for the notion of knowledge as tied to particular contexts of production and for knowledge which is coded in the languages, beliefs and practices of particular groups, making it inaccessible to others.

The following section extends the logic of these observations to the contexts and structures which typically comprise the capital goods project.

**Knowledge management in the capital goods sector**

Knowledge management is seen as particularly difficult to execute effectively in the project context which underpins capital goods production (Shapiro, 1999; Gann and Salter, 1998; Gann, 2000; Coombs and Hull, 1997; Davies and Brady, 2000; Brady and Davies 2003; Bresnen et al., 2003; Fernie et al., 2003; Ruuska and Vartiainen, 2005). In particular, knowledge management activity is viewed as hamstrung by the prevailing business and operational conditions which characterise such projects: their “one-off” and temporary nature, the structural fragmentation inherent in their organisation, the presence of culturally disparate professions, the project rather than business process focus of many of the firms associated with projects and the typically low-levels of inter-organisational trust stemming from divergent interests. This section considers these issues in detail. The literature drawn upon ranges across research into construction projects, complex products development and IT systems; however, the focus here is upon generic issues for knowledge generation and sharing in projects.
Low levels of trust

As noted, one of the key requirements for co-operative knowledge creation and sharing between parties is trust. Problematically, for a number of reasons, trust is difficult to build in the context of projects. A key problem within projects is that knowledge exchanging networks rarely have an opportunity to develop because of their task-focused nature (Koskinen et al., 2003). Time pressures also mean project actors simply do not have time to become familiar with one another’s perspectives and as a consequence they depend more upon assumptions about one another’s roles than actual experience. As Gail (1994) has noted with respect to construction projects, assumptions about other actors’ likely intentions and actions tend to be negative.

Fragmented networks

Large-scale projects (such as the one discussed in this paper) tend to be multi-technology and multi-organisational. Such projects rely on a wide range of inputs and expertise drawn from a host of other organisations including the customer, suppliers and numerous other organisations in both the public and private sectors (McLoughlin et al., 2000). Such arrangements tend to result in extreme complexity in terms of relationships, communications and the assembly and use of knowledge. The fragmented nature of work and the need to meet diverse client goals hamper the ability of firms to assimilate, and indeed even to recognise the value of, knowledge generated in other parts of a project (Koskinen et al., 2003). Indeed, clients themselves often comprise differing groups with differing perceptions and objectives. Suchman (1994), for instance, argues that ‘the client’ (e.g. for a complex product like a computer system) is, upon closer inspection, itself comprised of “…multiple constituencies, each with its own professional identities and views of the others” (p.32). Cherns and Bryant (1984) reinforce the point by describing the construction client as “…a complex of interest groups, some congruent, some competing.” (p.181). As such, the knowledge demands and outputs of these groups are likely to be very different, with the consequence that capital goods clients are themselves also likely to comprise numerous sites of knowledge production and consumption. Attempts to exchange knowledge can therefore also be expected to encounter difficulties resulting from strong institutional, professional and contractual demarcations as noted in construction (IPRA, 1992), complex products (Shapiro, 1999) and projects generally Koskinen et al., (2003).

Contractual culture

As a body of knowledge, project management generally advocates tight hierarchical divisions and control within the project (Thomas and Buckle, 2004). This has three key effects on knowledge exchange. Firstly, the hierarchical organisation of projects means that the contractor’s knowledge and experience is often separated from the client by a management tier of consultants. Therefore, unless contractors are leading the project themselves they rarely have the opportunity to suggest improvements (based on their expertise) directly to the client. Secondly, the formal project processes which characterise project management (rigid deadlines, work break-down structure, critical
paths and stage gates) also break up the learning process by preventing knowledge from persisting for the necessary gestation period (Miller, 1995). Thirdly, contractually-defined supply relationships, typical of construction and other contract based industries, are often litigious in nature, encouraging a climate of inter-organisational mistrust which further undermines the possibilities for knowledge sharing between organisations (Miozzo and Ivory, 1998).

Lack of repeatability

Learning within and across projects can also be difficult simply because projects, by their very nature, are usually novel in at least some respects. It has been noted that contractors focussing on similar projects can begin to build some competencies in areas such as bidding (see, for example, Brady and Davies (2003) with respect to complex products), but it remains that the majority of projects make this difficult by presenting technological and social variation (see, for example Slaughter (2000) with respect to construction). Projects are also in a state of continuous flux in terms of the material, the personnel and the information they create. That is, they do not develop the ‘steady-state’ routines (Levitt and March, 1988) that allow knowledge to be captured and reinforced (Bresnen, et. al., 2003). Over the life of the project, knowledge may be lost purely as a result of team members moving to other projects (Gann and Salter, 2000). Relatedly, Coombs and Hull (1998) note that project-based organisations tend typically to be focussed almost wholly on project completion and that project teams are disbanded and re-deployed on new projects as soon as possible, often before lessons learned can be shared (Keegan and Turner, 2001).

Summary

The conclusion that projects are not places to expect knowledge management excellence appears fairly inescapable. The nature of projects in terms of their lack of repeatability and routinisation, their often hard-nosed contractual culture when dealing with supply chains and contractors, hierarchical management and the fragmented communities of actors which comprise them, all point to a gloomy prognosis for knowledge creation and exchange.

Research approach and methodology

Our approach to exploring these issues constitutes a detailed analysis of what it is that the organisation’s networks, and the institutions, actors and technologies and other material resources that constitute them, actually do (Coombs and Hull, 1998). Shapiro’s (1999) review of the literature on learning/knowledge management issues notes the paucity of research in the area of the capital goods projects. Our aim is to start to redress this problem by examining the specific case of a complex project involving a mix of construction and new technology procurement. Accordingly, given the state of current
understanding in this area, our methodology was designed to provide a ‘rich’ description of the knowledge management issues in this currently under-researched and far from fully understood area where, nevertheless, significant practical and more conceptual insights might be gained.

The principal method of research was through interviews with key staff in relevant departments, business units and supply organisations. A thematic interview outline was prepared for each interview, although in every case interviewees were invited to broaden the depth and scope of the discussion. Each outline comprised a set of brainstormed ‘themes’ to be discussed and some specific questions aimed at establishing points of fact or the validity of information gained from previous interviews. Themes and questions were developed as the research progressed. Each interview involved at least two members of the research team and lasted between 1 and 3 hours. The research team itself was a multi-disciplinary one comprising of three social scientists, an economist and an engineer allowing varying perspectives to be brought to bear on the interpretation of interview material.

Interviews for the case study were undertaking with 13 individuals. These were with contractors (3), suppliers (1), consultants (2), NWL Project Managers (2), NWL senior staff (3), Operations Managers (2). The interviews were recorded and edited transcriptions, based on two independent sets of interview notes, were made available for correction and comment by the interviewees.

The case study itself was one of three case studies that were the focus of a larger research project concerned with knowledge and supply chain management in complex projects. The NWL case study was particularly interesting because it comprised the procurement of a technology which stood outside the experience of the client. While our original interests were in knowledge management for procurement, we also noted the importance of knowledge management much further on in the project life cycle, including post-delivery and the embedding of the technology into the client's operations. This observation, and the exploration of its implications, became the basis of this paper.

The case study is reported below as a largely linear account of the unfolding of the project from its initial feasibility and procurement through construction and finally to its embedding in the operations of the client. The unfolding of the case study is considered largely in terms of the key knowledge management activities that occurred as the project progressed. Through our analysis of the interview material we came to see the key problem for this client as one of creating knowledge in one context that could be transferred to, and embedded in, another context (e.g. between stages of the project or between those directly associated with the project and those elsewhere in the commissioning organisation’s business). We thus came to see the embedding of knowledge as a matter of different groups at different stages in the project process creating knowledge iteratively in conjunction with the supply chain, and other key supply side actors such as consultants, and thereafter of inter-stage and inter-group knowledge transfer where deemed appropriate.
One useful way of examining the role of these different contexts was to reflect upon knowledge generation and sharing practices as they were distributed across the different stages of the project. With this in mind we have labelled what we see as the key stages of learning and knowledge management as: 1) pre-project learning (scoping, developing options and feasibility studies); 2) detailed design and construction (the application and potential development of existing project management skills); 3) operational and post-commission learning (absorbing and developing knowledge relevant to operations); and 4) organisational learning (embedding what has been learned from the project in the parent organisation). We have used these stages as the organising principle of the paper. The nature of each of these four stages is explored below in the context of the case study.

Case study background

The Regional Sludge Treatment Centre (RSTC) is a £122m state-of-the-art sludge drying facility built between 1993 and 2002 by Northumbrian Water Limited (NWL) to serve the UK’s Northeast region. The building of the plant was prompted primarily by a 1991 EU directive banning sea disposal (initially by 2003 but subsequently brought forward to 2000). This required, in effect, that NWL find ways to render the end product inert so that alternative means of disposal could be used. With the RSTC in place at Bran Sands, sewage sludge is now collected from a number of sites across the region (the first point of processing) to be transferred (mainly by ship and, to a lesser degree, by road and pipeline) for final treatment at Bran Sands. Sludge produced at the Bran Sands Effluent Treatment Works, which handles industrial effluent from Teesside industry, is also transferred to the sludge treatment facility.

The core requirements for the sludge treatment technology were that it should be safe, flexible, secure, economic and manageable over a 20 year time-horizon. Drying, rather than incineration, was decided upon at an early stage because of the negative public perceptions associated with incineration. The drying process converts the sludge into inert granules or pellets with a variety of possible downstream uses, for example, in agriculture, horticulture, land reclamation, or as a fuel. The technology adopted employs the direct drying approach whereby the sludge is in direct contact with hot-air. The sludge is rotated inside a drum with hot air passing through it. The RSTC project, deemed a great success externally and within NWL, has attracted world-wide attention and has placed NWL at the leading edge of sludge treatment amongst water utilities.

The RSTC itself, the focus of our research, was essentially a construction project built around a core process technology – the sludge drying plant. In keeping with its past experience of large capital goods projects, NWL made extensive use of consultants and suppliers in the design and construction of the RSTC, but operated the plant itself. NWL was therefore both the customer for, and user of, the plant. At the time of the project, NWL had a long history of capital goods investment but of a relatively straightforward
'civil engineering' nature (i.e. reservoirs, pipelines, settlement tanks and storage tanks). A sludge drying plant, by contrast, constitutes a chemical processing plant and, therefore, a significantly more complex proposition. The RSTC was built in two phases, with the second phase mirroring the first in overall design, in order to allow a period of learning between the two phases.

Pre-project learning: procurement and conceptual design

Large expensive projects like Bran Sands constitute a high risk for clients such as NWL, not least because if they do not procure the right solution their operations will be adversely affected in the long-term. As such there are strong motivations to generate the knowledge that will ensure that mistakes are not made. NWL’s task was particularly difficult here as the technology identified to accomplish its requirements, although not new to the world, was unfamiliar to the Investment Delivery Team (project team) and alien to their normal operations. The technology therefore required that NWL staff climb a steep learning curve that would allow them not only to make correct procurement choices but also to manage the operations of the plant once it was transferred to them.

The knowledge NWL needed in order to make the right procurement choices resided in the supply base. Moreover, NWL recognised that it required a certain level of prior knowledge, or absorptive capacity (Cohen and Levinthal, 1990) for that knowledge to be of use. NWL had to be able to determine, for instance, what sorts of solutions were implied by ‘direct’ or alternatively ‘indirect’ drying. It also had to identify a solution which could offer high levels of operational safety and the required flexibility of end product. To this end, NWL instigated a managed design competition by paying each of four short-listed competing technology suppliers to work up their designs to a high level of completion. As part of that competition, while protecting the proprietary knowledge of each of the bidders, NWL also encouraged and managed the production and sharing of knowledge between the bidders by making available knowledge that had been jointly created with NWL. This meant not only that the solution arrived at was optimised, but that NWL and its consultant Environmental Technology (ENTEC) were able learn more about what was possible, at what cost and with what ultimate result. NWL could be said, therefore, to have turned its supplier selection process into a formalised knowledge-generating process by putting in place appropriate incentives for its suppliers. Indeed, not only did the suppliers have the motivation to create knowledge but they operated in a

As a project manager at Bran Sands noted in respect of this: “The days when sewage flowed in one end of the plant and out of the other of its own accord have long gone”. The radical nature of the change for NWL was also reflected in the following statement made by a Health and Safety Executive visitor to the plant which was reported as: “Welcome to the chemical industry”.

Indirect drying involves a sheet of metal that heats the sludge as the sludge moves over it. This method can involve either a series of plates, modules that extrude the sludge, or a drum.

I.e. a dried pellet with high calorific value making it suitable as a fertilizer or a fuel.
manner which implied a great deal of trust not normally associated with the contracting process in construction. NWL ensured that this was possible by re-configuring the normal tendering process in this particular way. The final selection was informed by consideration of whole-life costs, the hazard potential of the process, energy consumption, transport costs, additive costs (e.g. polyelectrolytes) and the type of dust produced.

**Detailed design and construction**

*Design*

Once the conceptual design was complete the requirements of the project were then outlined and costs estimated. However, before any project proceeds at NWL it is tested to ensure that it genuinely "holds water" in economic and technical terms. Consultants from the project evaluation unit in NWL, therefore, scrutinised the proposed project, their job being to "pull the project apart", to identify possible problems and to agree final solutions. Involving other people from within NWL helped the core project team avoid the formation of “tunnel vision” by bringing in experience from other projects. This is one way of ensuring that previous project knowledge is made available to new projects - here project-to-project learning occurs through the involvement of an 'experienced eye'.

Another important route for previous project experience to find its way into new projects was through what NWL called the Project Sponsor. In this case the transfer of knowledge was motivated by the need to ensure that projects delivered by enthusiastic investment delivery teams actually served the operational needs of the business. Experience had shown that technical staff in lead positions on projects often took a very 'engineering' or ‘front end’ view of what was required (i.e. that not enough attention was paid to the downstream needs of operations). Traditionally in NWL there had been a clear split between construction and operations, so that only those aspects of the project which had been commissioned became the operational manager's responsibility. NWL's response to this problem was to create the Project Sponsor role. The Project Sponsor is tasked to oversee a project from feasibility through to completion and in so doing ensures that the project meets the business’s overall needs. Project Sponsors also tend to have an operations background and so bring an ‘operator’s eye’ to the project. The Bran Sands project was one of the first NWL projects in which a Project Sponsor was used. The key aim of the Project Sponsor role was to use operations knowledge to guide the design solutions proposed by the investment delivery team and their consultants. As such, the Project Sponsor can be seen as a boundary-spanner supporting knowledge-flow between the two communities.

*Construction*

In the building phase, the frenetic knowledge-creating activity which characterised the early feasibility and design phase of the project was replaced by a focus on taking what
had been specified and delivering it (on time and to cost). Introducing new knowledge at this stage is more difficult as designs and contracts of work are finalised. Activities aimed at the generation of new knowledge (or activities requiring new knowledge such as innovation) can be perceived as getting in the way of the main goal of delivering the project. Clients and contractors in particular have strong motivations to focus on completion. Clients face lost income (and in the case of NWL, regulatory penalties) for late completion, while contractors face contractually-agreed penalties for late completion and loss of profit if they are over-budget.

To render the construction process as manageable as possible, traditional project management encourages sharp demarcations between project activities. For example, in phase one of the project, NWL insisted that those contractors working on both the Regional Sludge Treatment Centre (RSTC) and the adjacent Effluent Treatment Works (ETW) should observe a ‘glass wall’ between the two developments despite the fact that they were intrinsically related and formed part of a larger coherent programme of developments. This meant that they were required to have distinct and separately managed project teams for the RSTC and the ETW. In effect this sacrificed potential resource-sharing and learning in favour of improved project manageability. Although relaxed in phase two, when the demands of the building programme were better understood, this practice remained in place for some aspects of the project.

The project management structure also reflected NWL’s desire to out-source most of the day-to-day project management function. The organisational arrangements on the project were such that suppliers worked for NWL’s consultant ENTEC. Although NWL worked hard to ensure open relationships with contractors and suppliers, subsequent ‘distance’ from the customer was felt by some contractors and suppliers to be a key barrier to knowledge exchange. Contractors also reported finding it difficult to “get engineers together” at NWL to give them presentations on new technologies and techniques, essentially due to pressures on their time.

Some of the contractors on the project did make efforts to liaise with each other more informally. For example, undertaking small but important electrical jobs for one another, lending fork lift trucks, getting together to arrange common services (e.g. food). This encouraged team building and made more effective use of resources.

What begins to emerge, nevertheless, as one looks across the life-cycle of the project, is a shift in the focus of actors initially towards and then away from knowledge management activities.

**Operational and post-commission learning**

The conclusion of the delivery phase of the project once again re-focused the attention of those involved onto knowledge creation and transfer. NWL shifted its resources from
project delivery to project operations as it faced the reality of having to embed its new acquisition into its operations. Complex capital goods require a good deal of embedding in their host - they rarely work entirely satisfactorily 'out of the box' and their operation is invariably improved over time through learning (Bohn, 1994). The RSTC was no different. Sewage sludge varies considerably in its characteristics from one location to another, which made it difficult to anticipate precisely how the technology would perform once fully commissioned. For NWL this meant a concerted effort at learning through identifying operational problems and developing solutions to them.

On the RSTC project the Design Operators Group (DOG) was the point of facilitation for much of this learning. The DOG involved operators, members of the Investment Delivery Team, Andritz (the manufacturer of the sludge drying equipment) and, where appropriate, other members of the supply chain. Meetings of the DOG were held monthly and were aimed at identifying difficulties with the equipment over the longer-term. NWL found the group useful in as much as they could “…talk though some of the operations issues…it is a very complex process plant”. More broadly, the group has also helped to build cohesion in the Bran Sands project team. It was felt that the scale of Bran Sands otherwise meant there were few opportunities for a comprehensive exchange of views (there were four operator shifts, a maintenance crew, managers, water quality operators and environmental analysts). On smaller projects a closer interaction between the sponsor and the user is possible and the normal core team meeting would suffice.

Andritz was also able to benefit from the DOG in terms of feedback to design by gaining access to information on the ‘actual’, as opposed to the ‘expected’, operation of equipment. As a consequence of this learning the air handling system was changed significantly: the efficiency and accessibility for maintenance of the duct work in and around the drying plant was improved substantially; access hatches and surveillance cameras for monitoring silos and screw conveyors were subsequently installed. The performance of the sludge cake silos was also improved. ¹

Moreover, it also provided opportunities for them to input into the running of the plant where operators were not following expected practice. So successful had this been for Andritz that it planned to instigate similar meetings with new clients. Interestingly, there was also some evidence that these relations were helped by institutional factors. In particular, for Andritz's engineers there was a certain level of professionalism associated with contributing to design improvement. As Andritz's contract manager commented "we are too much engineers to say its your [NWL’s] problem”.

A company-wide Strategic Sludge Group (SSG) comprised of management, from director-level upward was also set up as a learning mechanism to ensure that the

¹ The phase-one operators had found that clogging occurred unless the silo was operated at less than half full. In phase 2, not only was access improved for ‘rodding out’, but the design was also improved to reduce clogging; the silo was made wider at the bottom to prevent bridging across the screws, which was causing the clogging.
organisation as a whole was able to respond effectively to new issues emerging from the sludge drying process. Although this was an investigative group and had no powers to instigate projects, the group could nevertheless smooth the way for research programmes. Because senior managers sat on the SSG it also made it a good forum to make (and rehearse) presentations that would bring particular problems to the attention of senior management in the business. From the perspective of operations and of the remaining Investment Delivery Team, the key objective of meetings with this group was to convince the business at large that its problems were serious enough to require attention.

The post-procurement phase also triggered within NWL the generation of new operational procedures, new skills and new working practices. This learning, however, also showed some of the difficulties of getting groups to exchange knowledge in a context where there are few perceived benefits in so doing. In the RSTC project, this issue was manifest in the project handover to operations. During this period it was noted by one operations respondent that there was no maintenance schedule or operating manuals in place when the RSTC was commissioned and that ‘data collection’ procedures for equipment had not been set up on time. A key reason for this was the late arrival of operations staff at the plant; operations management were placed on site only four months prior to handover and some staff only after the plant was running. The timing of this was determined ultimately by the business rather than the operators or investment delivery team and reflected, one project manager felt, an underestimation of the uncertainties and complexities facing operations in the context of a newly-adopted and unfamiliar technology. It also reflected, however, the largely 'project delivery' focus of the Investment Delivery Team. It was clear that something of a knowledge ‘watershed’ existed between them and the operators. However, it appears that in this case, it was less a divide between two ‘communities’ or ‘activity systems’ that rendered them non-communicative (the DOG shows that they were well able to communicate), as a lack of motivation in the project team to spend time on tasks defined by them as non-core (such as helping prepare operating manuals or procedures or ensuring that they were provided by suppliers). In other words they were not properly motivated or resourced to do so.

Operational learning was another important area of activity for NWL, though again one which pointed to the critical importance of the motivation to learn. A key problem for NWL was a lack of experience of similar technologies amongst their operators. Consequently, they were faced with having to learn virtually from scratch about a technology that was quite alien to them. An initial strategy had involved bringing in staff from outside the water industry from more chemical-process oriented sectors. However, a recruitment ban in force at NWL meant that staff had to be sourced internally. While at the project level it was felt that, ideally, experience would have come half from sludge drying and half from the process industries, ultimately, of the thirty-two staff required to operate the plant, only nine were from the process industries. Staff at NWL had also been on a two week visit to a similar facility in the US but found it difficult to assimilate the knowledge they needed through observation alone and in the two weeks they had available to them. Consequently, Andritz's role, while it involved transferring knowledge through manuals and training support, also involved supporting NWL operators while
they learned how to run the plant; Adritz made itself available online to run the plant remotely should NWL operators encounter serious difficulties.

While it was recognised that a non-ideal staff profile had slowed learning, progress was made nevertheless. Aiding this progress was a deliberately flexible management approach in which operations shift teams functioned relatively autonomously. Each shift developed its own approach and then distributed this learning through the rotation of operators through different teams and roles. As this process went on the knowledge developed by the shift teams was captured by operations managers and formalised into standard operating procedures. However, despite a strong team spirit amongst the RSTC operators, conflicts of interest and barriers to learning did still occur. Operational staff at Bran Sands took time, for example, to accept the need for formal monitoring procedures. In the ‘early days’ the sludge mix (the wet cake and dried pre-mix material) was tested by ‘feel’ alone; an operator would squeeze the mix to estimate its water content. Clearly, although the operator knew whether the mixture was ‘OK’, he could not state precisely what the dry-solid mix was. While it was recognised that tacit skills like these were an essential part of the day-to-day running of the plant, it was also recognised by operations management that a more systematic monitoring process was needed to collect data useful in the longitudinal monitoring of the plant. Problematically, because the operators’ focus was upon day-to-day operations, they found it difficult to see how this added value. However, the problem proved not to be insurmountable. To encourage operators on board with the data collection process NWL ensured that they were aware of what the information was being used for (i.e. long-range operational planning and process performance measurement). This suggests that knowledge processes (production, transfer and use) need to be carefully and sensitively managed, particularly in cases where the usefulness of the knowledge generated is viewed differently by different groups.

Organisational learning

The broader NWL business has also had to adjust, in terms of company-wide operating procedures, to owning a technology which, for it at least, was radically new (a processing plant rather than a treatment works). However, the business was more distant from the mundane day-to-day reality of operating the plant and was not necessarily in touch with operational issues. Clearly identifiable problems such as those aired at the SSG, which could form the basis for well-defined research projects, travelled more easily around the organisation and were able to attract attention and funding. Other issues (such as outdated procedures) were less visible and had to be solved on a more ad-hoc basis locally. NWL’s existing purchasing procedure, for instance, had to be modified locally at Bran Sands in order to secure the delivery of spares into the plant in time to keep the process running (continuous chemical processing plants cannot wait for spares). Similarly, in order to deal with the complexities associated with doing maintenance work on the RSTC, operators at Bran Sands developed their own ‘Work Control Permits’. These controlled who was allowed to work on the plant and what they were allowed to do.
Arguably, organisational, geographical and even cognitive distance from the complex operational realities constituted by Bran Sands acted as a hindrance to the transfer of knowledge across NWL and to NWL’s broader adjustment to the new technology. In some senses Bran Sands was treated as an island of competence by the business. It regarded the RSTC, in particular, as a unique and isolated activity which was unlikely to become part of ongoing business activities (i.e. it was unlikely to build more plants of this nature).

**Discussion and conclusions**

The case study presented makes it clear that the incentives to engage in knowledge generation and sharing wax and wane over the life of a project. In this case high levels of knowledge creation characterised by feasibility, followed by an apparent dip in interest as the project entered its building phase, followed by renewed learning for those actors who remained involved in the project, as attempts were made to embed the technology into the client organisation. Although, at this stage of the project, suppliers and contractors were focussed on projects elsewhere, it was still possible for the client to draw them back into the learning process by paying them (as in the case of Andritz).

The case study also made clear that knowledge creation and knowledge sharing occurs best when participants gain mutual advantage from so doing. The sharing and co-generation of knowledge between different groups and project stages was also best achieved when those involved all saw the value of the knowledge being generated. Problems occurred when different groups perceived and defined the project’s goals differently, thereby valuing particular knowledge differently. In this case study, for example, project managers placed less emphasis on drawing from either operational experience or on providing knowledge for future operations. This can be explained by the tendency for project delivery teams to view their success in terms of the measurable parameters of delivery (e.g. on time and to cost) and, therefore, to give priority to generating the knowledge that will enable them to do that. For similar reasons, operations management had problems getting operators formally to record codifiable operations data, and project and operations staff both experienced difficulties in getting the business to respond to the new demands made by an unfamiliar technology (see Table 1 below).

**Table 1. The knowledge strategies of key groups in the project**

<table>
<thead>
<tr>
<th>Approach to Knowledge</th>
<th>Operators</th>
<th>Design Engineers</th>
<th>Investment Delivery team</th>
<th>Project Sponsor</th>
</tr>
</thead>
<tbody>
<tr>
<td>General approach to knowledge</td>
<td>Refine operational knowledge to</td>
<td>Advance knowledge along technology trajectory. Project is</td>
<td>Specification focuses new knowledge creation</td>
<td>Knowledge as ‘experience’ – exploited through</td>
</tr>
</tbody>
</table>

9 The reasons for this stemmed largely from project actors subscribing to the idea that completion times and costs were a greater threat to success than imperfect design choices.
<table>
<thead>
<tr>
<th>(knowledge strategy)</th>
<th>improve operations.</th>
<th>source of experimentation and learning.</th>
<th>to ensure key project goals are met on time and to budget.</th>
<th>application to new problems and domains.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach to sharing knowledge with the other groups</td>
<td>Externalising knowledge of problems may lead to support in solving them.</td>
<td>Sharing knowledge across organisational and community boundaries may lead to useful design feedback.</td>
<td>Knowledge shared internally to solve delivery problems.</td>
<td>Sharing knowledge about operations can improve ‘design for operation’.</td>
</tr>
<tr>
<td>Attitude to inputs to knowledge from outside</td>
<td>Knowledge inputs from outside augments own learning.</td>
<td>Knowledge input from other groups welcome (product improvement).</td>
<td>Knowledge inputs from outside can form a complication to project delivery.</td>
<td>This role is about knowledge flow. Knowledge inputs flow from operations to design.</td>
</tr>
<tr>
<td>Generating knowledge for other groups</td>
<td>Expect inputs (e.g. manuals, results from research projects) not outputs</td>
<td>Accepted part of a ‘professional’ engineering service.</td>
<td>Completion of the physical project is the ‘traditional’ priority.</td>
<td>This is a key function of the sharing of experience.</td>
</tr>
</tbody>
</table>

It follows from this that successful knowledge management in the dynamic and complex environment constituted by projects must begin from an understanding of where the motivations to exchange knowledge do or do not exist. This analysis would be underpinned by extensive existing knowledge of the commercial, strategic and institutional drivers of different groups in the project process. With this knowledge, the case study also demonstrates that it is possible to then manufacture ‘temporary contexts’ that will support knowledge creation and sharing where it is weak. The DOG was a good example of how this can be achieved. The DOG, in effect, attacked the divisions (cultural, temporal and contractual) between communities such as designers, contractors and operators by bringing them together and giving them a common focus on identifying and solving specific operation/design problems.

The findings of the case study, and in particular the success of the DOG in motivating knowledge creation and exchange between different groups, also have implications for the extent to which social barriers to knowledge creation and exchange (i.e. the human-centred approach to knowledge management) should be seen as determining influences on knowledge management activity. The impact of communities (Bresnen et al., 2003) and activity systems (Blackler, 1993; Blackler et al., 1998,) in limiting knowledge sharing, for example, was not as strong as expected. This is surprising, given the gulf between the communities of designers (Andritz), operators and investment delivery, in terms of their approach to knowledge generation and sharing (see Table 1 above). The DOG, however, seemed well able to overcome such difficulties and to create a shared space, rather like that envisaged by Nonaka and Takeuchi (1995) and Nonaka and Konno (1998), in which all three communities alluded to in the table viewed knowledge exchange positively. The key strength of the DOG in this regard was in getting
participants to focus on the same knowledge problems, but from the perspective of their own interests. In other words, whereas designers saw feedback for improved design, operators saw issues for operations (with long-term operations in mind) and project managers saw a ‘snagging list’ (the conclusion of which would allow them to close-out the project). The case study shows, therefore, that while project barriers clearly do exist, and while project managers should be aware of them, they should also feel confident that (temporary) organisational spaces can be created that will re-configure motivations and support knowledge creation and exchange where needed.

In terms of creating a suitable management response to these findings, the issue of motivation seems an appropriate focus. The likely motivations of communities and groups in different parts and stages of the project to generate and share knowledge need to be identified and, where weak, addressed. Where necessary, existing ways of organising need to be re-thought to facilitate and motivate necessary knowledge sharing. As this case study shows, there are plenty of tools available to do just this (research projects, out-of-project goal-orientated teams, project reviews, project sponsors and so forth) so what should concern project managers is less the type of tools that are available and more the motivations amongst their staff to use them. So for example, project and business managers should be seeking to create shared spaces (in this case the DOG) and scenarios (the design competition) capable of constructing a common focus for knowledge creation and sharing. Knowledge-focussed roles, i.e. roles that can formally bridge the gaps between key groups and communities, particularly those with limited existing incentives to share knowledge, should also be considered. However, those in these roles should be empowered to effect changes in behaviour where they deem it necessary. Contractually-binding incentives should also be in place to ensure that promised knowledge transfer takes place (e.g. the production of manuals) on time. Some issues may be harder to address because they stem from the setting of conflicting priorities elsewhere in the business, for example, the fact that staff were not released for training until close to the operations state date. These are not matters that can be rectified at the project level but need to be negotiated between the project team and the business at an early stage.

It remains that a single case study, while able to evidence the importance of an issue, in this case the importance of motivation in generating and sharing knowledge in projects, cannot provide enough data to document all of the interventions which may be successful in encouraging it. Further, the findings of a single case study, in what is technologically a very specific context, may prove not to be generalisable to other contexts. Nevertheless, we would anticipate that much will be generalisable to other contexts in which projects are the key organising principle. In this case study, the motivations to share knowledge appeared to be distributed across groups (designers, operators, contractors, suppliers) in ways that appear logical without reference to the specifics of this case study. Further research in this area should, therefore, seek to: a) confirm the findings of this case study in other contexts (i.e. confirm the importance of motivation in the generation and sharing of knowledge); and b) to explore the nature of the sorts of interventions taken in other contexts (i.e. to create a comprehensive toolkit of interventions). We anticipate pursuing a
research agenda that would foreground practical issues in knowledge management within projects with a focus on the means through which knowledge transfer problems are solved by project managers and workers through planning and through down-stream interventions in existing processes.

References


