

**Mediating Artefacts, Boundary Objects and the Social Construction
of Knowledge**

Allan Macpherson, Oswald Jones and Helen Oakes

**Manchester Metropolitan University Business School
Aytoun Street
Manchester
M1 3GH**

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Introduction

It is noteworthy that theories associated with knowledge management and organizational learning focus on economic outputs and the creation of competitive success (Easterby-Smith and Lyles, 2003). Despite a growing critique of these approaches (Lave and Wenger, 1991; Blackler et al., 1993; Swan and Scarbrough, 2001; Easterby-Smith and Lyles, 2003) studies still have a bias towards knowledge as a resource and cognitive learning (Anonymous, forthcoming). Alternatively, writers from a social constructionist perspective argue that knowledge creation and learning occurs through interaction within a unique social milieu (Easterby-Smith and Araujo, 1999). Since individual action is mediated by collective expectations, organizational learning takes place *between* rather than *within* individuals (Weick and Roberts, 1996). When 'shared meanings are continually maintained or modified... these are acts that create, sustain or modify the organization's culture' (Cook and Yanow, 1996, p440). The assumption is that knowledge or learning is evident in situated activity or 'knowing' and is dependent on the social context in which it occurs; knowing is 'an integral and inseparable aspect of social practice' (Lave and Wenger, 1991, p31).

Since organizations are sites of collective activity, acting in concert with others requires a shared understanding of that activity (Easterby-Smith et al., 2000). Knowledge, or 'knowing', is created in communities where the meaning of activity has to be negotiated and agreed, at least temporarily, accommodating a variety of perspectives in order to generate a shared capability for action. It is suggested that, this collective understanding is sustained by social interactions through mediating devices (Engeström, 1990; Walsh and Ungson, 1991; Blackler et al., 1993) and the deployment of discursive resources (Oswick et al., 2000; Heracleous and Barrett, 2001; Holman et al., 2002; Hopkinson, 2003). While dialogue is at the heart of knowledge creation and learning it is not necessarily cyclical as suggested by Nonaka and Takeuchi (1995). Foregrounding the influence of language highlights the possibility of many outcomes where knowledge or 'knowing' is dependent on the resolution of ambiguities that persist within communities (Alvesson, 1993; Tsoukas and Vladimirou, 2001). This emerging 'linguistic turn' in organization studies mirrors concerns in wider social sciences regarding the significance of language in the construction and reconstruction of social practice (Alvesson and Karreman, 2000). It is in language that managers learn of, and adapt, collective understandings of

legitimate actions. It highlights a concern with how actors may draw on a variety of discursive devices to interpret or construct organizational reality and the accepted way of thinking about, or ordering practical activities (Heracleous and Marshak, 2004).

Our aim in this paper is to explore the way organizational activities and tools provide focal points of learning between organizational communities. The nature of practice-based learning means investment in past activities and different organizational communities create tensions. Strategic renewal means that new activities and new ways of knowing have to be established across practice boundaries. In this paper, we first explore the potential for conflict and dissonance in knowledge creation. We then outline how shared practices depend on shared understandings and identify the central role of mediating devices in this process. By bringing together activity theory (Engeström, 2001) and the role of boundary objects (Carlile, 2004) we show how ‘objects of activity’ provide a focal point for achieving, temporarily at least, a shared understanding of practice which supported strategic renewal in *PresMed*.

Conflict and Dissonance - Knowledge Creation and Knowing

Nonaka and Takeuchi (1995) have been criticised for presenting a view of knowledge creation and learning that ignores relational and political conflicts that occur in organizations. Engeström (2000), for example, is particularly critical of knowledge creation and learning as a cyclical and sympathetic process of conflict-free socializing. Expansive learning occurs more from ‘conflictual *questioning* of the existing standard practice’ (Engeström, 2000, p968, italics in original). For Cook and Brown (1999) the process of interaction occurs not between knowledge types (tacit and explicit, individual and collective), but between the interplay and interactions in the social and physical world. Making tacit knowledge explicit and establishing common understanding may be a challenge to the existing order of things. If different interests arise, developing common knowledge is a political process of negotiation (Wenger, 1998; Brown and Duguid, 2001).

Berger and Luckmann (1966) argue that reality is an ongoing ‘dialectical process composed of the three moments of externalisation, objectivation and internalization’ (ibid, p149) and to be a part of society is to participate in this dialectic. Rather than a process of tacit and explicit knowledge exchange, the process of objectivation requires dialogue and agreement of knowledge–reality. In short, it is theory building through generalising that requires knowledge to be tested, revised and

accepted. It is not cyclical, but iterative and contested, with historical experiences and current contexts creating tensions (Tsoukas, 1996). Through this process, knowledge is socially constructed and 'objectified' in concrete routines, processes, rules and procedures that are shared collectively, but experienced individually. Knowledge is thus iterative, active, contested and has historicity; it is a 'project in progress' (Lanzara and Patriotta, 2001). Knowledge work is conducted at all levels of the organization as workers interact, improvise and negotiate in specific and uncertain contexts (Tsoukas and Vladimirou, 2001). In this view, knowledge, or knowing, is a situated practical activity. In this view, to understand knowledge work we need to pay attention to how organization members identify and negotiate uncertainties in day-to-day activities. Researchers should address 'new areas of knowledge and how they become established, it involves attention to practical knowledge as well as commodifiable, theoretical knowledge' (Blackler *et al*, 1993, p1019).

Gherardi and Nicolini (2002) argue that explanations of knowledge management and learning often overemphasize mutuality in understanding and ignore the discontinuity and conflict that co-exist within knowledge systems. They point to tensions between consonance and cacophony in the establishment of meaning. Challenging accepted assumptions within a community requires a break from the accepted order, creating disorder and conflict before new assumptions are accepted or rejected. When members engage in conversations, opinions, and conflict during the governance of the organization these activities help to trigger learning, and unlearning, since without 'vivid opposition, an organization deteriorates rapidly and loses its ability to invent and implement new strategies' (Hedberg, 1981, p.17). As Hopkinson (2003) observes:

'a theoretic discourse may lose meaning, and even cause confusion, when imported to an organization. It may contradict the prior constructions on the basis of which organizational members act.' (p1965).

Reflections occur when accepted knowledge systems (discourses) break down or are challenged (Starbuck and Hedberg, 2003). This can be achieved by attending to divergent viewpoints from outside traditional communities (Zeitsma et al., 2002), through physical relocation (Sole and Edmonson, 2002), encouraging interaction across intra- and inter-organizational boundaries (Child and Heavens, 2003; Holmqvist, 2003), or recruiting staff who do not conform to established

organizational codes (March, 1991). There may be a variety of potential ‘stories’ available to organizational members and contexts are a ‘contested terrain across which different classificatory systems slug it out’ (Scarbrough, 1996, p200). Given the diversity of interests and potential sites of conflict, if organizations are to function, agreement has to be reached, or accommodations made, on the appropriate order of things (Robichaud et al., 2004). As Giroux and Taylor (2002) contend in their study of the wide-spread adoption of quality management practices:

‘translating specialists’ knowledge into a language that top management can understand is not sufficient to transform it into accepted truth. For a solution to a problem to be viewed as such, it must be legitimized within a particular social context’ (p509)

A ‘community of practice’ is one in which language and discourse forms the basis of tacit understanding. Consequently, the adoption of a quality management discourse required that it be presented in a way that corresponded to the explicit interests of those whose support was sought (Giroux and Taylor, 2002). Developing collective understanding is fundamental to successful organizational activity and requires attention to the discursive activities and structures that enables the process. Thus, these views ‘situate knowledge and knowledge management squarely within social and political systems of meaning’ (Swan and Scarbrough, 2001, p921).

Objects of Activity and Mediating Collective Learning

Discursive practices and texts act as a filtering intervention to produce a shared body of knowledge which informs what we do but at the same time it is supported by that activity (Suddaby and Greenwood, 2005). Shared discourse can occur both through conflict and collaboration as meanings are negotiated (Blackler and McDonald, 2000; Gherardi and Nicolini, 2002). However, for collective learning to occur requires a shared agreement of accepted practice either through shared ‘theories of action’, shared ‘sensemaking’, or ‘social norms of behaviour’. Early work in this field concentrated on how ‘communities of practice’ define the range of legitimate behaviours for members (Lave and Wenger, 1991) and provide a socializing mechanism through which an organization’s ‘situated curriculum’ is transferred to new members (Gherardi et al., 1998). Learning is embedded within the everyday practices as members participate in an organization’s society (Nicolini and

Mezner, 1995), what Brown and Duguid (1991) call 'learning-in-working'. Fundamentally, organizations are sites of collective activity in which acting in concert with others requires mutual understanding of that activity (Easterby-Smith et al., 2000). However, where novelty is evident in the environment, or where new knowledge has been made available, past certainties, understandings and dependencies become unreliable and are open to challenge. Communities of practice must be able to negotiate this uncertainty if they are to survive and adapt through new shared concepts of knowing. To make sense of novelty requires integration of diverse and interacting knowledge domains and a commitment to learn about the consequences and dependencies generated by new knowledge (Carlile, 2004). It is suggested that collective understanding can be shaped and sustained by social interactions through mediating devices (Engeström, 1990; Walsh and Ungson, 1991; Blackler et al., 1993) and the employment of a variety of discursive resources (Oswick et al., 2000; Heracleous and Barrett, 2001; Holman et al., 2002; Hopkinson, 2003). As such, 'language is a means by which to turn thinking into a social medium, a way of sharing our world with others' (Elkjaer, 1999, p86).

It is in language that organizational members learn of, and adapt, collective understandings of legitimate actions. Suddaby and Greenwood (2005), for example, argue that taking a rhetorical lens to analyze strategies of legitimacy employed during changes in the 'Big 5' accounting firms captures the frayed, proximate and direct relationship between talk, action and meaning. This emerging 'linguistic turn' in organization studies mirrors concerns in wider social sciences regarding the significance of language, not just as a tool used to represent reality, but also as a tool that is employed to actively construct that reality (Alvesson and Kärreman, 2000). Indeed, Dewey (1958) argues that since language is used as a tool to generate meaning (in communication with others and oneself), it is itself a form of action. If linguistic resources and rhetorical devices create and sustain discourses (Foucault, 1972) that define organizational realities, they are tools of knowledge construction (Holman et al., 2002), and they can help to create a shared identity (Orlikowski, 2002; Hardy et al., 2005). As such, practical activities in organizations are constructed not objective and language, rather than simply reflecting organizational activities, is central to their construction (Green, 2004).

This brings to the fore a concern with discourse and discursive structures that mediate organizational conversations (Heracleous and Barrett, 2001; Doolin, 2003).

Actors may draw on a variety of discursive devices to interpret and construct the accepted way of thinking about, or ordering practical activities (Heracleous and Marshak, 2004). Indeed, understanding the aesthetics of storytelling may provide managers with an effective discursive device that can be employed to influence and direct organizational learning (Taylor et al., 2002). Understanding rhetorical practices may help in developing strategies for managers to enlist others into their vision of the organization (Green, 2004; Sillince, 2005; Suddaby and Greenwood, 2005). As Oswick et al (2000, p888) note, this means that communicative practices, ‘as the dynamic and interactive process through which the dominant “organizational reality” is socially mediated’ are central to understanding how multiple perspectives are reconciled towards a shared capacity for action.

Drawing on work by Star (1989), Carlile (2002) proposes that sharing knowledge to allow collective learning between different knowledge domains requires more than knowledge exchange. It must overcome inherent characteristics of situated ‘knowledge in practice’, or knowing, including: localization (specificity to problems or context); embeddedness (technologies or rules of thumb and methods used in a given practice); and investment in practice (path dependencies). ‘Boundary objects’ acting at the interface of knowledge domains provide a shared syntax which allow exploration of semantic differences and help the joint transformation of knowledge between practice communities (Carlile, 2004). Boundary objects, he argues, act as an ‘integrating device’ through which knowledge is transformed and collective learning can be achieved. However, re-using past knowledge to represent differences and dependencies generated through access to novel situations and interactions will circumscribe opportunities to understand consequences and possibilities. To benefit from boundary interactions requires a degree of political will to ‘trade off’ past certainties and current practices in order to integrate and resolve differences such that a pragmatic solution is achieved (Carlile, 2004). Tensions between actors need to be managed to balance the competing needs of participants and representatives which requires a shared identity with the project (Hardy et al., 2005). As such, Carlile (2004) argues that boundary objects have different capacities to represent common knowledge and can act as integrating devices through which knowledge and learning are represented and mediated. Depending on the degree of novelty faced, he considers that boundary objects such as technical drawings, simulation tools, and models, provide an infrastructure through which differences can be explored and resolved.

These ideas are similar to work in activity theory. Objects, including tools, procedures processes and accepted practices are expressions of cognitive norms and expected standards of activity since they represent inter-subjective understandings and modes of action (Miettinen and Virkkunen, 2005). In addition, tools, instruments and rules are used as mediating devices between subject-object activities in constructing those representations. Consequently, 'mediating artefacts' are central to both the representation of past learning and the construction of new meanings (Engeström, 1987, 1990; Blackler et al., 2000; Engeström, 2001; Engeström and Blackler, 2005; Miettinen and Virkkunen, 2005). In an organization where practices and activities are conducted in socially situated contexts, contradictions and tensions exist as well as agreement (Engeström, 1990). Within an activity system specific elements of knowledge and practices of 'knowing' are contested because identities, conceptions of activity and mediating artefacts are held in dynamic rather than static relations (Engeström, 1999).

The complexity and quality of knowledge relations are influenced by contradictions that exist both within the activity system and between activity systems. Such contradictions and uncertainties can lead to a transformation of the firm if those in power are prepared to question existing artefacts and prevailing conceptions of their activity. In resolving this tension new hypothesis are collectively generated about the conduct of practice such that new practical tools, processes and procedures are defined and 'objects are constructed by actors as they make sense, name, stabilize, represent and enact foci for their actions and activities' (Engeström and Blackler, 2005, p310). Once contradictions are acknowledged, reconciled and internalised managers may (re)conceptualise their activity as the better application of linear problem-solving techniques, they may innovate by improving integration of knowledge, or they may innovate through collaboration and knowledge creation (Blackler, 1995). The latter initiates cycles of 'expansive learning' (Engeström, 2001) that occupies managers in the self-productive creation and adoption of new conceptions of their activity (Blackler *et al.*, 1999; 2000).

Resolving tensions created by the clash of past and novel knowledge requires reflection on current practice and 'the routines themselves must be made in to an object of enquiry' (Miettinen and Virkkunen, 2005, p451). In this sense, the notion of 'object' or 'mediating artefact' brings in to focus practical activity that is conducted in the collective search for new realities (learning process). Thus, boundary objects are

not just tools that, as Carlile (2004) argues, enable the transfer, translation and transformation of knowledge, but they direct attention to ‘objects of activity’ where different practice-based communities can develop shared practices, or knowing. Objects, or mediating devices, are ‘artifacts of knowing’ through and against which different communities can represent, interpret and contribute to the understanding of ongoing and unfolding activities (Ewenstein and Whyte, 2005). Objects have different integrating capacities, and participants will ultimately have different abilities (or motivations), to negotiate the process of knowledge transformation and collective learning (Carlile, 2004).

This turns our attention to instruments that act between a subject and the object of activity: the technologies that are used by the communities to make sense of existing practices. However, our interest is the practical activities that are in some way altered through the process. Generating shared meanings requires collective acceptance of the purpose and design of tools, systems, routines, procedures and other organizational artefacts. These represent the state of knowing and shared learning within the organizational community, but some members of that community may be more able, or more willing, to influence the form and content of these artefacts and activities. Thus, analysis of how shared understanding of activities are developed demands that we pay attention to: the activities and systems that support organizational interactions and dialogue; the variety of knowledge communities and their levels of influence in shaping new activities and practices; and the objects/mediating devices through which shared understandings are negotiated. Understanding the role of boundary objects and mediating artefacts in (re)defining knowing is at once both inherently important, and pragmatic, in the day-to-day practice of management and learning.

Research Methods

The empirical material is based on a longitudinal case study of a medium-sized manufacturing firm, with a turnover of £10m, based in a Lancashire town. *PresMed* employs approximately 70 staff engaged on the manufacture of autoclaves used for sterilizing medical instruments. The main UK market for autoclaves is the NHS as well as independent doctors, dentists and veterinary surgeons. Approximately 45% of sales are made in the UK and international markets are based on traditional links with Commonwealth countries such as India, Australia and Canada. The

managerial structure follows a conventional functional approach associated with 'medium-technology' manufacturing companies. Our research began soon after the appointment of a new MD who was employed by the owners to regenerate a company that was moribund and directionless. During the two years we have studied *PresMed* it has undergone substantial changes and is now a much more dynamic and successful organization. It is the analysis of this transformation which forms the core of our paper.

Data were acquired from a variety of sources including three interviews with the MD at roughly six monthly intervals. Other members of the management team were also interviewed including the production manager who was promoted to operations director during the course of the study. The production manager was recruited by the MD for his experience, gained in a variety of manufacturing companies, of modern manufacturing techniques such as Kan-ban, JIT and Six-Sigma. These two, along with the finance manager (now finance director) provided the leadership for *PresMed's* renewal. Other data were acquired during a SWOT analysis carried out by the second author to help with the development of a coherent strategy within the company. All eight departmental managers were interviewed for approximately one hour during which time they evaluated *PresMed's* SWOT from their function's perspective. The outcomes of these sessions were then summarised using Decision Explorer to develop conceptual maps for each of the eight functions. These conceptual maps then provided the basis for a strategy session involving all the managers under the guidance of the MD. This three hour session was taped as the group attempted to reconcile their differences to develop a coherent and a consensual strategy for the next five years. Other data were collected during 10 site visits by the second author over the two-year period. These data included informal discussions with a wide range of shopfloor and junior white-collar staff such as material controllers and quality engineers. A digital camera was used to record shopfloor changes as the traditional method of holding large quantities of stock and WIP was replaced by a lean manufacturing approach. As part of a larger project, the operations director agreed to keep an electronic diary in which he recorded significant events as well as his personal and the company's response to those events (he provided 15 diaries entries over an 18 month period). This access, negotiated with the MD and the operations director, provided a detailed account of the change process during a two-year period.

Mediating Organizational Learning

In 2002 the owners of *PresMed* recruited a dynamic new MD who began to transform the moribund organization. TG was appointed because of his extensive managerial experience in a range of large and small organizations. His ability to ‘turn-around’ a previously failing firm was particularly significant in his appointment. The transformation included recruiting a production manager, restructuring the existing management team and developing a stronger team spirit:

‘You can probably tell I’m not a dictatorial, shouting type of person. It’s more of picking up the strengths, identifying the weaknesses and trying to get the team to pull together. From an operations point of view the team was a complete mess. They weren’t a team they were enemies. Everyone was looking after themselves.’

Managers and employees at all levels in *PresMed* were encouraged to ‘let go’ of past knowledge and open-up to new ideas. Over a two-year period the company gradually began to take on the principles of a learning organization. In the study, we identify ways in which collective learning was mediated through a range of boundary objects. These objects included: a SWOT analysis which helped reconcile different views on *PresMed’s* strategic direction; a PC-based training course (Master Production Scheduling) to improve scheduling and reduce conflict related to stock-levels; and WIP (work-in-progress) and a process known as Failure Mode Effects Analysis (FMEA) which was used to deal with endemic quality problems. As Carlile (2004) points out, such objects potentially act as integrating devices by providing employees with shared identities associated with the change project. Certainly within *PresMed*, these three devices provided an infrastructure through which differences were explored and reconciled.

The first ‘object of activity’ that we discuss is the use of a SWOT analysis to carry out a strategic review of *PresMed*. As part of his plan to promote a stronger sense of team spirit amongst the management team, two staff from MMU Business School (MMUBS) agreed to facilitate the analysis. Each functional manager was interviewed individually and asked to identify the strengths, weaknesses, opportunities and threats from his/her perspective. Because of the importance of sales to the company all three senior sales staff were interviewed (Table 1). While one member of the MMUBS carried out the interview the other used *Decision Explorer* to

‘map’ the main concepts identified during the interview. At the end of the session, the map was shown to the interviewee and they were asked to indicate whether or not the diagram successfully captured their view of the organization. Nine interviews were carried out over a two-day period and this was followed by a strategic review which involved all the participants in a ‘round-table’ session.

Table 1 Functional SWOT Analysis

	STRENGTH	WEAKNESS	OPPORTUNITY	THREAT
Sales Manager	Market leader Top 5 globally Quality Trading partners	Buying attitude Communication R&D projects	US market New MD	Saturated markets Legislation EU competitors
International Sales	50% home market Brand name Customer relations	Knowledge share Delivery delays 50% home market	Linking sales & production Improve image New dealers	Too much product diversity Dealership & service
UK Sales	Awareness of legislation NHS profits After sales service	Forecasting & production links Product reliability & quality	Technical know-how Improve product development	Euro competition Litigation Overseas competition
Product Manager	Product range Technical competence	Use of agents Lost NHS Poor quality Shortages/MRP	Small medical practitioners Russia New MD	Lack of profit Management morale
MD	Benchtop sterilisers Workforce skills Team leadership	Poor design Quality systems Communication HR utilisation	Export growth Far East Dental practices Parallel supply US market	East Europe supply Legislation
R&D	In-house design Manufacturing	Too many models Sales team Poor communications	New MD NHS reforms Better forecasting Better supply links New markets	Legislation Saturated markets Blame culture
Finance	Improved internal procedures & control	High stock levels Internal comm. Sales review Quality systems Location	Staff involvement Supply chain Customer base Joint problem solving	Too close to customers & suppliers Cashflow Currency variations Blame culture
QA	Service engineers ISO 9000/2000 Reputation Sector leader	Shopfloor demotivation Quality systems Prices Distributors	New product development In-house design	Service + warranty claims Conflict with sales Dead-on-arrivals
Purchasing		High stocks Shortages Email Lack of training Design	Consolidation of stocks Stores reorganization	Contract review system Blame culture

The strategic review began with the MMUBS team presenting a summary of each participant’s SWOT analysis. As Table 1 illustrates, there was remarkably little agreement amongst the team about any of the four elements. Even the sales manager and his two assistants had very different views about the main issues confronting *PresMed*. Nevertheless, as a means of promoting discussion amongst the management team, the most common elements from the SWOT analysis were presented to the group (Table 2: Pre-SWOT), the main points of which had been agreed in advance by the MMUBS team with the managing director, TG. This diagram provided the starting point for a three hour discussion in which the team developed a coherent view relating to the main SWOT factors which impacted on the business. TG pointed out at the beginning of the session:

‘There are probably differing views in any of these exercises. As individuals we may have extreme views but as a group we all realise that, sort of, we have to give a little – find the middle-ground’.

Table 2 Organizational SWOT Analysis

	STRENGTH	WEAKNESS	OPPORTUNITY	THREAT
Pre-SWOT Strategy Session	Technical know-how Image and brand	Quality systems Stores and WIP Communication	MD New markets Supply chain Stores reorganization	Profits Saturated markets Legislation Supply chain Blame culture Product quality
Post-SWOT Strategy Session	Product range Product specification Technological intelligence Customer base Flexibility Market knowledge	Lack of profits Communications Perceived quality Supply chain integration Key account dependency	Market share Cost reduction Quality systems Market diversification Supply chain relationships	Lack of profits Competition Key suppliers Marker consolidation Product range Legislation

The SWOT analysis provided focal point through which the team began to reconcile their different viewpoints. There were points of conflict between the production manager, the sales manager and the head of purchasing related to both the high levels of stock retained by the stores and problems created by component shortages that often resulted in large numbers of ‘part-built’ machines. In the main, primarily as a result of the MD’s calming influence, there was a mature and creative discussion that helped establish a coherent view amongst the group about the

company's main strengths and weaknesses. While the discussion was open and all were allowed to air their views the direction was significantly shaped by TG (comment to second author before strategy meeting):

'I've got a clear idea of what our problems are and what we've got to do about them. But as I've said, I'm not a dictatorial sort of person - I want bring the team together and let them reach their own conclusions. For example, quality was a separate function and I know that it's going to be difficult for everyone to take-on responsibility for quality.'

By the end of the session, the team had agreed five points for each element of the SWOT analysis. These, were ranked in order of importance to the business. As Table 3 illustrates, 'product range and specification' was the main strength while lack of profits was regarded as the most important weakness.

Table 3. Agreed Analysis of Importance for SWOT

LEVEL OF IMPORTANCE	1	2	3	4	5
Strengths	Product range & specification	Technological intelligence	Large customer base	Flexible response	Market knowledge
Weaknesses	Lack of profit	Communication	Product quality	Integration of supply chain	Key account dependency
Opportunities	Market share	Costs reduction	Quality systems	Diversification (product/market)	Supply chain relationships
Threats	Profitability	Competitors	Key suppliers & market consolidation	Product range	Legislation

NB: on a five-point scale 1 represents the most important while 5 the least.

There was substantial evidence that the session provided a basis for longer-term organizational learning. First, a number of cross-functional project teams consisting of three/four employees were given the task of dealing with internal issues identified during the SWOT analysis. For example, one team examined issues associated with supply chain management; another with the quality systems and so on. Managers were not allowed to be on the team examining issues which were part of their own functional responsibility. Second, the MD dealt with poor communication between functions by insisting that one day per week had to be 'email free'. This encouraged managers to 'get out of their offices' and discuss problems face-to-face rather than firing-off aggressive emails to other departments. Third, the transformation was not without its human cost. Some reorganization was conducted and a number of shop

floor staff were made redundant. Of particular note, however, is that the session helped to identify those individuals who were unable or unwilling to commit to the new way of working. As the MD indicated, those not committed to reconciliation would be encouraged to leave:

‘If there isn’t a mutual path forward then I’m quite, not happy, but comfortable that I’ll sit down and bring things to an end if needs be - because in the past I’ve had to’ (laughs).

One of the cross-functional teams gave the production manager responsibility for examining the firm’s stock holding. It was noted that stores management was incredibly inefficient. For example, the stores area took up considerably more space than the main assembly area. At the same time, it was not unusual for urgent materials to be brought from the southeast by taxi to prevent assembly hold-ups. In addition, there were very high levels of stock holding. The extraordinarily high levels of stock held in September 2004 (see Table 4) were the result of two main factors. First, there was a major failure of material control which emanated from the desire to ‘save money’ by ordering in unrealistically high quantities to obtain a cheaper price per part. For example, relatively low value items were often ordered in quantities sufficient for two or three years of production. It was not unusual for such components to become obsolete before stock levels were exhausted. The other problem was a lack of coordination between material control and marketing. *PresMed* had four core models (Zenith, Century, Omega and Classic) as well as a number of product variations. Although there was a cursory attempt to forecast annual sales this was not done effectively. In addition, the sales director vigorously defended his right to offer customers whatever product they wanted in order to make a sale. This inefficiency meant that the purchasing manager was constantly forced to order large quantities of stock to ensure that any model could be immediately programmed.

Table 4. Stock Value

	September 2004	September 2005	September 2006 (target)
Raw material	£580,000	£396,000	£250,000
Work-in-progress	£152,000	£99,000	£80,000
Finished goods	£340,000	£157,000	£100,000
Total stock	£1,057,000	£625,000	£430,000

In the review of stock-holding practices conducted by the production manager, it was made clear to the purchasing manager (DD), who was the most visible representative of the previous regime, that the firm could no longer tolerate the inefficiencies of the existing system. Although DD received a considerable amount of coaching and cajoling from the MD and the production manager, he was unable to break free of a mindset associated with large stockholdings and high WIP. When it became obvious that a 'lean' approach to stock levels was inevitable he decided to leave *PresMed*. Indeed, both the sales manager and the head of purchasing left the company within six months of the SWOT day. After taking responsibility for the stores, the production manager (GW) immediately implemented a number of changes.

'I've acquired the stores to manage in addition to my existing duties. I'm now charged with ensuring that material is available to match the production schedule and with reducing the inventory volume and value to a minimum. I'll begin by reviewing the processes and redesigning them to reduce administration, red tape, confusion and delays' (GW – diary entry).

An essential element of his plan was to find a suitable vehicle to encourage his new staff to adopt modern material control practices. A brief internet search provided a mass of potential training courses from which he selected a DVD-based package: *Master Production Scheduling (MPS)*. MPS is designed to enable staff to make effective use of MRPII and ERP systems. Three members of the purchasing team and two stores workers were instructed by GW to complete the training course. They were all able to do this during their normal working day. MPS provided a rigorous guide to the principles underpinning and effective balance between supply and demand to minimise stock levels without endangering production. Exhibit 1 (as appendix) describes the programme of work for the first of ten sessions. The discussion and activity generated through participation on the course had an immediate impact on employee attitudes to stock and WIP. Within six months of taking over responsibility for the stores GW's team reduced the value of stock from over £1million to £625,000. His target is to further reduce this to approximately £400,000 by September 2006 (Table 4).

The third mediating device was based on a system known as FMEA which was developed by the US military in the 1940s to improve the reliability of its equipment. Although in its original incarnation FMEA was primarily aimed at eliminating product design faults it was also adopted as a quality assurance tool. It

was in this latter role that it was used in *PresMed* to bring together a team consisting of the production manager, shopfloor employees, purchasing, quality control, service and marketing. The FMEA tool provided GW with an extremely powerful approach to the elimination of persistent quality problems (see Appendix 1). The approach was relatively straight-forward and followed this three-stage process:

1. persistent faults were identified from records held by quality assurance;
2. the ‘failure mode’ was then evaluated by establishing where the fault would be identified (during the production process; in final test; during operation by the customer).
3. the ‘effect analysis’ then encouraged staff to consider the likely impact of a fault (safety or legal problems; high customer dissatisfaction; medium customer dissatisfaction; little customer dissatisfaction; fault undetectable by customer).

By undertaking this analysis many persistent faults were rapidly eliminated by the team. Of much more importance to this particular analysis is the way in which FMEA helped provide a common sense of purpose amongst a disparate and largely antagonistic group. As pointed out by TG, managers, as well as other employees, were locked into a ‘blame culture’ in which every failure was the responsibility of someone else within the organization. Making use of FMEA definitely aided in creating a common understanding and created a shared project identity (TG):

‘I think it was getting people to break down what the issues were and try and solve the causes of the problems rather than patching. Previously, as I said, there had been a lot of fire-fighting, making things work so you can get them (products) out of the door, but actually just perpetuating the problem. We’ve created an opportunity to do it properly by taking things off-line. So, as I say, it’s just breaking those things down; it’s doing the things that you would normally do from a quality improvement point of view.’

Discussion: Mediating Artefacts and Objects of Activity

We extend earlier work on boundary objects (Carlile, 2002; 2004) by incorporating insight from activity theory to stress the importance of situated practical activities (Engeström, 1990) and communicative action in the social construction of knowing (Orlikowski, 2002). Carlile (2004) suggests a three-stage communication model for the transfer of knowledge across boundaries. A syntactic boundary

(transferring) is followed by a semantic boundary (translation) and, finally, a pragmatic boundary through which knowledge is transformed. We agree that boundary objects help to provide a focus for representing existing knowledge. This process was clearly observably within *PresMed* as the various groups, including senior managers, engaged in the SWOT analysis to represent their understanding of issues facing the firm and began to deal with deep-seated problems. However, as Blackler and Engeström (2005, p313) observe, objects ‘powerfully illustrate the intimacy of relations between the material and the social, the centrality of artefacts to both thought and action, and the complex relationships between objects and values’. Consequently, we can conceptualize Carlile’s ‘boundary objects’ as mediating artefacts that represent the current state of shared knowledge but also recognize that they provide a template that informs action. For ‘mediating artefacts’ to encourage and support knowledge transformation, they have to represent new shared conceptions of activity, and these have to be enacted in new contexts. There has to be a pragmatic commitment to new activities, which occur not through the mediating artefacts themselves, but through the engagement and activities of those within and between communities (Carlile, (2004). As noted earlier, the employment of a variety of discursive devices (Heracleous and Marshak, 2004), and the structure and deployment of discursive resources (Heracleous and Barrett, 2001; Suddaby and Greenwood, 2005) are central to understanding the way in which communicative actions shape practical activities in organizations (Orlikowski, 2002). Miettinen and Virkkunen (2005, p443, our italics) describe the role of objects within activity theory; ‘interaction between the human agent and its object is mediated by cultural means. The basic types of means are tools and signs. An individual internalizes these means during socialization *by participating in common activities with other humans*’.

As demonstrated above, when TG took over as MD of *PresMed* there was little consensus amongst the management team about causes of problems facing the firm and certainly none about the way in which things could be improved. Each of the main functional areas (sales, quality, production, finance, stock control) sought to blame each other. Staff were unwilling to reflect on their own shortcoming in terms of two major issues confronting the company: poor product quality and high stock levels. TG the new MD took a structured approach to problem-solving which involved engaging cross-functional groups in ‘object-orientated’ activities against which current practices were (re-)examined:

'People do work together and feel by going through what to some of us are standard processes and systems are useful tools. And, you know, they don't have to be based on opinion or have a rivalry thing. It's everyone aiming to sort out a general problem, we'll map it out and I think to a certain extent similar exercise will come out of these improvement projects we're looking at' (FMEA and MPS).

In the paper, we have outlined three new 'mediating artefacts' that helped scrutinise past activities highlighted different understanding between functions. These artefacts helped coalesce understanding between practice communities and contributed to the creation of a learning culture in *PresMed*. Obtaining some measure of agreement about the strategic direction, in turn, encouraged a more positive approach to dealing with issues such as quality and stock control. In this regard, a computer-based learning package, *Master Production Scheduling*, enabled the stores and stock control teams to understand the mechanics of meeting production needs with lower stock levels. A quality management tool, FMEA, was effective in dealing with poor product quality.

As discussed in our literature review, these three mediating artefacts supported collective learning; encouraged social interaction; provided a forum for debate amongst different knowledge communities; and included specific 'boundary objects' through which collective knowledge was negotiated. At one level it would be possible to portray the case as a simple shift from non-learning to learning *via* key mediating artefacts such as MPS and FMEA. However, we suggest that a mediating artefact (or boundary object) is not simply a tool for representing existing knowledge; a knowledge repository in Carlile's (2002) terms. Rather, the mediating artefact supports 'modes of action' or practices in which staff engage during the process of knowledge transformation (Miettinen and Virkkunen, 2005). The initial SWOT analysis, using *Decision Explorer*, provided a shared syntax to transfer knowledge and was a mechanism for representing understanding about issues facing the firm. However, the practices and activities of the purchasing manager and sales director did not change. In this case the SWOT analysis provided a mechanism for dialogue and interaction, leading to shared representation of common knowledge, but practical change was not initially achieved.

Thus, mediating artefacts such as SWOT, MPS and FMEA provide a way to represent and share collective understanding. The figures in Table 4 demonstrates attainment of a shared understanding that lower stock levels were good practice and

over time represented successful transformation of workplace activities based on the principles of lean production. Thus, mediating artefacts allow the expression of cognitive norms and *expected* standards of activity. Mediating artefacts provide a means of representing common knowledge and a mechanism for transferring and translating knowledge at the boundary between knowledge communities (Carlile, 2002, 2004). Mediating artefacts (boundary objects) also provide an infrastructure that can dismantle boundaries to understanding (Bowker and Star, 1999). But such artefacts do not transform knowing; social practices, including communicative actions are essential to the transformation of activities (O'Donnell et al., 2000; Orlikowski, 2002).

Collective practice requires a common understanding and an acceptance of norms amongst members of a community. The case illustrates the way in which creation of social spaces for dialogue can encourage the adoption of new norms and new practices. Within *PresMed* this was not necessarily a conflict-free process of collaborative learning. Rather, it involved significant tensions as well as the exercise of power to encourage, cajole and convince different communities of the importance of changing both attitudes to, and practices of, quality management and stock control. The SWOT analysis allowed senior staff to outline their views about issues facing the organization. Bringing participants together for an intensive half-day strategy session forced them to reconcile their narrow functional perspectives with other organizational views in order to create a shared project identity (Orlikowski, 2002). In Table 5 we briefly outline the objects of activity, the associated social practices, and the political power associated with each of the three mediating artefacts. In bringing in outsiders (MMUBS) to undertake a SWOT analysis, TG forced his senior management team to acknowledge and reconcile their deep differences. This process ultimately led to the 'resignation' of the sales director when it became obvious that he could not change his *modus operandi*. Similarly, the purchasing manager also failed to make the transition to new working practices, and when it became obvious that his approach would not be tolerated he found another job. By leaving, he removed a 'blockage' to the adoption of lean production principles amongst other staff members. Although the quality manager did not leave it was made very clear to him that a new approach was going to be adopted. Hence, the production manager was given responsibility for implementing the principles of FMEA.

Table 5. Mediating Objects and Social Practices

Mediating artefact	Object of activity	Associated activity (social practices)	Political power
SWOT	Develop a 5-year strategy and create esprit-de-corp amongst SMT	Prompting individual reflection on functional issues combined with group-based discussions to provide coherent view.	TG forced most powerful senior managers (sales director) to reconcile their views with others in the firm
MPS	Reduce stock levels and WIP	Individual computer-based learning combined with team-based problem solving.	Resignation of purchasing manager signalled to staff that they had to adopt new practices
FMEA	Identify the causes of persistent quality problems	Structured and collective analysis of quality problems to identify root causes rather than surface manifestations.	Team led by production manager rather than quality manager

TG did allow the MMUBS team complete freedom to present the composite view expressed in the ‘pre-SWOT strategy session’ (Table 2). Furthermore, the second author introduced the strategy session and briefly summarised the views of each participant. However, before the interviews or the strategy session had taken place, the MD indicated (to the 2nd author) that he knew the main problems confronting *PresMed*. This is not to suggest that the process of consultation was meaningless; rather, TG used his considerable ‘social skills’ (Fligstein, 1997) to shape the nature of the debate in helping the team identify the key factors which he believed had to be addressed. After the strategy session, the team appeared to agree about *PresMed*’s main weaknesses and there was a concerted effort to improve internal communications. As discussed above, TG nominated Fridays ‘email free’ so that managers had to resolve their problems face-to-face rather than ending emails in which they blamed each other. Again, this confirms that participants have to be willing to trade-off competing demands through creation of a shared identity (Hardy *et al*, 2005). However, the move to a leaner mode of production was resisted strongly by the purchasing manager who, although he agreed about the main problems, could not relinquish past knowledge since his expertise was ‘at stake’ (Carlile, 2004). He eventually left, and the production manager was then able to use MPS to support changes to stock control practices. FMEA facilitated cross-community dialogue focused on quality control but its adoption was driven by: agreement established

though the SWOT analysis; the willingness (or otherwise) of functional specialists to acknowledge past antagonisms and differences; and by power invested in the production manager that flowed from that process.

MPS and FMEA were extremely powerful in helping represent past knowledge and collective understanding and consequently were objects that represented potential ‘modes of action’ (Miettinen and Virkkunen, 2005). However, it was not necessarily these ‘mediating artefacts’ that supported knowledge transformation. It was the ‘objects of activity’ and their associated social practices (Table 5) that provided the impetus for real learning. Moreover, at all levels, politics and power were evident in modes of information exchange, in the way knowledge was represented and in the choice of practices that support transformation. Thus, operational problem-solving did not occur until tensions were resolved at a more strategic level, and consensus was achieved on the ‘object of activity’. Carlile (2004) accepts that a degree of ‘political will’ is required to resolve long-standing disputes at the pragmatic boundary; our argument is that political processes are also evident at both the syntactic and semantic stages. Effective information processing depends on the creation/establishment of a ‘common lexicon’ to share and access knowledge. Similarly, knowledge translation requires the creation of common shared meaning (semantic) within a group. Both of these are choices open to political influence. We demonstrate that TG (MD) exercised his power to shape both the syntactical and the semantic boundaries. For example, he recognised that simply processing information *via* email (syntactic) was having a divisive impact on working relationships. Therefore, he encouraged more face-to-face communication in the SWOT analysis and by email-free Fridays. Hence, functional managers had to resolve their differences rather than simply blame other people for failures. However, the choice of fora for this information exchange (syntactic) and the representation of collective understanding about the nature of difficulties facing the firm (semantic) was heavily influenced by his power (as MD) and his social skills of persuasion. But the transformation of ‘knowledge in practice’ⁱ requires pragmatic engagement in social practices and not just the pragmatic representation of knowledge in boundary objects. Our study confirms the centrality of mediating artefacts/boundary objects in representing and constructing common knowledge (Carlile, 2002; 2004; Star, 1989). We also show that pragmatic engagement in social practices while attending to

'objects of activity' are central the transformation of Carlile's definition of 'knowledge in practice' or knowing.

Conclusions

We agree that boundary objects are at once both practical and political (Carlile, 2002). Where our work extends this conceptualisation is that according to Carlile (2004) organizational politics only become a factor in the final (pragmatic) stage. As demonstrated above, politics and power are prevalent at syntactic and semantic levels as well as the pragmatic. In addition, whereas Carlile considers boundary objects facilitate knowledge transformation at a pragmatic level we show how such transformation is significantly dependent on activities that support dialogue and interaction. Further, we stress the importance of leaders having the political will and power to influence the process of change (Buchanan and Boddy, 1992). In that sense, knowledge transformation is fundamentally influenced by the creation of social learning spaces (Coopey and Burgoyne, 2000), but it is also shaped by discursive resources that are available to participants (Heracleous and Marshak, 2004).

Mediating artefacts or boundary objects promote a range of associated 'objects of activity'. It is these 'objects of activity' around which social practices and political actions are focused. In turn, it is these activities, at the heart of which lie communicative actions (Orlikowski, 2002), which create and transform knowledge rather than the mediating artefacts or boundary objects themselves. Within *PresMed* this process also began the redefinition of day-to-day social practices, or knowing, around communicative actions. For example, pre-MPS, the focus of stock-control and stores personnel was on trying to ensure that any model/combination of models could be programmed as required by the sales director. Post-MPS, the focus of activity was on the reduction of excess stock while at the same time programming for future demand. This in itself required much higher elements of cooperation and understanding between production, stock control and sales than previously had been the case. Strategic renewal requires knowledge transformation. It is the accepted routines of practices that must be made into objects of enquiry (Miettinen and Virkkunen, 2005). It is important to attend to 'objects of activity' and their associated social practices in order to understand the social construction and transformation of knowing. Thus we agree that the concept of organizational objects (Carlile, 2002, 2004; Engeström and Blackler, 2005) is of particular significance for organization

studies in general and learning and knowledge transformation in particular. Research into objects, their associated social activities and discursive practices is an important and pragmatic way of understanding strategic renewal and organizational learning.

(7,800 words)

ⁱ Carlile's (2002, p445) defines 'knowledge in practice' as localized, embedded and invested in practice. This is the same qualities of knowledge that others define as knowing. See for example Blackler (1995) and Orlikowski (2002).

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Appendix 1

EXHIBIT 1

Session 1 tasks

- Discuss and document the company's planning processes including, if necessary, the need for a Sales and Operations Plan.
- Decide whether you can get access to your current or proposed master scheduling system (preferable) or use the spreadsheet workshop example which you received when you purchased this course.
- **Workshop**
 - open the workshop spreadsheet master production schedule page "MPS 123"
 - if you are able to access a master scheduling system, set up a database with a master schedule item part number 123, a suitable description and any other data needed by the system, identify the key features of the system in particular the way forecast is entered and the way the production schedule is entered and displayed
 - enter the sales forecast and MPS at date of receipt line on the system as shown on the spreadsheet
 - make sure you understand the projected available balance calculation
 - set up a second database or spreadsheet with quantities and lead times that are relevant to your business