

Viewing Boundary ‘Objects’ as Boundary Constructions

W. David Holford*, Mehran Ebrahimi*, Omar Aktouf† and Laurent Simon†

Abstract

Empirical results from a qualitative study within an important North American aircraft engine manufacturing company allows us to propose an alternative framework for achieving effective knowledge sharing based on the boundary construction concept. Tapping into Latour’s [13] epistemological insights of mutual transformation, hybridization and inter-reciprocal relationship between the object and subject, it is proposed that effective boundary objects are in a constant flux of actual (and potential) co-construction and re-construction at the hands of interacting actors. This boundary constructing, in turn, leads to enriched organizational sense-making.

Effective sharing of knowledge occurs as a result of boundary construction/actor interactions that are enabled within a shared context (ba) where mutual trust and respect, empathy and openness to others’ differences, and requisite variety predominate. Such an environment is consistent with Enriquez’s [7] concept of differentiated work group environments, whereby emancipation of the self co-exists with identification to the other.

1. Introduction

In the following paper, we first review certain epistemological ‘slips’ within the literature on boundary objects (BO’s); and how these can subtly mislead us towards identifying success factors for effective boundary conditions that are self-evident yet often tautological prescriptions which fail to place sufficient emphasis on the actors’ role towards ensuring their effectiveness. This is followed by an alternative epistemological view that allows us to shift our level of analysis towards which critical enabling conditions allow for effective knowledge sharing via the boundary object/actor interaction.

Empirical results from the aircraft engine manufacturing context allows us to further build on our initial propositions, whereby a holistic yet practical conceptual framework for achieving

effective knowledge sharing based on the boundary construction concept is presented.

2. Literature and epistemological review of boundary objects

According to Star and Griesemer [30], BO’s are “things” which coordinate the perspectives as well as serve the information needs of the intersecting social worlds of various actors towards a given purpose. The authors presented four categories of BO’s: 1) *repositories* (e.g. databases) of objects “indexed in a standardized fashion” which individuals can borrow for their own purposes; 2) *ideal types* which are vague and therefore locally adaptable; 3) *standardized forms* which are applicable to dispersed work groups due to the emphasis placed on methods of common communication over long distances; and 4) *coincident boundaries* which are common objects with the same boundaries but have different internal contents depending on the interests and perspectives of each party. The concept of boundary objects has been used in the fields of knowledge management (KM), information technologies, project management and communities of practice. Examples include engineering sketches [11], standardized reporting forms [4], engineering drawings [3], physical prototypes [5], project timelines such as Gantt and PERT charts [38], as well as more abstract forms such as concepts [37] and definitions [1].

2.1 Different gradations in duality between the object and subject

From an epistemological viewpoint, Star and Griesemer’s [30] concept of BO’s gives rise to a gradation in duality between the object and subject, depending on the category in question. Repositories and standardized forms imply the strongest degrees of duality – even though it is implicit that the individual who interacts with such categories of BO’s will use a certain degree of subjective interpretation, it is hoped,

* Department of Management and Technology, School of Management, University of Quebec at Montreal (UQAM), Montreal, Canada – E-mail: holford_w_david@uqam.ca and ebrahimi_mehran@uqam.ca

† Department of Management, HEC Montréal, Montreal, Canada – E-mail: omar.aktouf@hec.ca and laurent.simon@hec.ca

especially in the field of information technology, that it is minimized across the use of codified knowledge that has been captured or constructed from the realms of both individual tacit knowledge and non-representational explicit knowledge. As for ideal types and coincident boundaries, there is an explicit recognition of the subject's active interpretation and viewpoints that comes into play, yet the object is assumed as being either an unchanging entity, or as a changing entity who's end-result is still clearly and discretely separate from the subject. Later interpretations of BO's have continued to imply varying degrees of duality between the subject (or actor-individual) and the object: "boundary objects are artifacts, documents, terms, concepts and *other forms of reification* around which communities of practice can organize their interconnections" [37, p. 107]; "a boundary object is any object that is relevant to the practices of multiple communities, but is used or viewed differently by each of them" [22, p. 650]. These epistemological subtleties are perhaps best summarized by Lutters [16, p. 35-36], who highlights Fahey and Prusak's [8] "critique of the conceptual foundations for most knowledge management projects", and most notably, the emphasis made on "knowledge stock to the detriment of knowledge flow", whereby the "boundary object concept only partially addresses this critique", since "it still suffers from an artifact-centric view of knowledge, rather than a process oriented perspective".

Lutters [16, p. 36-37] argues that despite this setback, BO's are still the best concept to go with since "there is at least an awareness of flows in which they are embedded and potential support for encapsulating informal, dynamic, and exception based information... [can] also provide for multiple perspectives on this shared information", and can be "viewed as the result of a complex negotiation process among multiple parties", thereby supporting KM's need to create a shared context. While Lutters' description on what BO's are supposed to achieve are laudable, how do practitioners (i.e. organizational members) ensure that this in fact occurs? Researchers have proposed that effective BO's are easily accessible, up-to-date, tangible [6] and concrete [1]. Yet some such as Sapsed and Salter [24] have suggested that their use may be limited. Here, the authors, in studying the use of project management tools in geographically dispersed organizations, found that BO's did not sustain their initial role of facilitating knowledge sharing and collaborative work between project

team members. They conclude that where there is very little social interaction (especially face-to-face), BO's lose their usefulness. Carlile [5], on the other hand, argues that BO's can either be beneficial or deleterious depending on the social context at hand. Carlile identifies three types of factors for generating useful BO's: 1) BO's as providing a common language for actors to represent their knowledge; 2) BO's as providing a means for actors to express different interpretations, thereby allowing the possibility for novelty to emerge; and 3) BO's as facilitators of processes which allow the actors to change the contents of the object in order for it to continue to be useful to all involved participants. But Carlile's level of analysis tends to imply BO's as being independent variables to the subject-actor, while simultaneously implying the subject-actor to be dependent on the BO. In the following subsection we draw upon epistemological insights from Latour [13] on the nature and relationship of the object and subject. This, in turn, will allow us to shift more emphasis on the active and dynamic role the actor has over the BO, and thereby attempt to shift our focus as to where and what the most pertinent 'success factors' are when speaking of effective boundary 'objects'.

2.2 Hybridization and inter-reciprocal relationship of the subject and object

Latour [13] criticizes the notion of Modern society because of its simplistic categorization of things, processes, human conduct, behavior, emotions and values which he refers to as the process of "purification". He explains that this process is based on viewing the Object (Nature) and the Subject (Society) as being pure distinct categories from one another. Latour explains that in reality such categories: 1) inter-penetrate one another in a process of hybridization; and 2) ceaselessly change and transform one another. Hence, Nature is affected, transformed, as well as contains aspects of Society and vice-versa (examples of Nature being re-organized or imprinted by Society includes the damming of rivers; genetic engineering of plant and animal life; air, water and land pollution, etc.). Or as Marcel Mauss [17] states: "With the human being, we cannot observe Nature without it having been transformed by culture". Rosaldo [23] also supports Latour's thesis of the hybridization of the Subject and Object by arguing that social analysts "can rarely, if ever, become detached observers" and that "there is no archimedian point from which to remove oneself

from the mutual conditioning of social relations and human knowledge”. Both Rosaldo and Latour see science in the same way as contemporary advanced scientific spheres who advocate regarding reality across the lenses of complexity (e.g. Heisenberg, Bohr, etc., who showed that the observer’s behavior affects the outcome of an experiment; or complexity theory which views everything as being intertwined in a dialectical inter-reciprocating fashion [25]).

Hence, the object is as much affected and transformed by the subject, as is the subject affected and transformed by the object. We can now reword the factors identified by Carlile for effective BO’s as follows: 1) the actors must provide a common language for them to effectively represent their respective knowledge across the help of a co-constructed or co-negotiated BO; 2) the actors must provide a means to express their different interpretations across the help of a co-negotiated BO; and 3) the actors must continually co-negotiate and co-transform the BO so as to maintain an on-going pertinence to all involved participants. This rewording changes the research aim from a linear-causal type question of ‘Which type of BO’s fulfill these conditions towards effective knowledge sharing?’ (Figure 1-A) to a more dialectic/holistic question of ‘Which enabling conditions encourage the needed interactions between the actors and the BO towards effective knowledge sharing?’ (Figure 1-B).

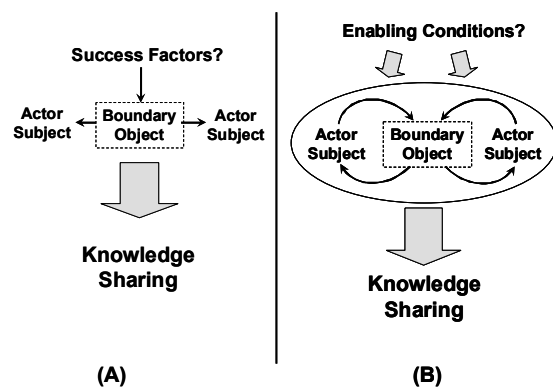


Figure 1-A. Linear causal approach
 Figure 1-B. Holistic-dialectic approach

2.3 Boundary constructions as an integral part of the sense-making process

The above argument rejoins Berger and Luckmann’s [2] human subjective interpretation (as mental, linguistic and physical acts) simultaneously shaping and being shaped by

social reality, whereby social reality, according to Latour [13], also includes Nature (Object). Hence, BO’s are shaped by actor-subjects, just as they also shape actor-subjects. Furthermore, this occurs in a dynamic and continuous manner. And just as Berger and Luckmann [2] speak of the social construction of reality, so can we speak of an on-going social construction of BO’s. Hence, we propose *boundary constructions* as an alternative term to BO’s.

When speaking of human interpretation, it is also important to consider the sense-making process as defined by Weick [33, p. 14]: “the concept of sense-making is valuable because it highlights the invention that precedes interpretation”. At the organizational level Weick [32, 34] sees it as involving enactment, selection and retention (ESR). Enactment is essentially the process in which people create and structure their environment as their environment creates and shapes them [19, 32, 34]. Enactment also involves the simultaneous comparison or retrospection with past experience (retention). Selection involves the imposition of various structures on enacted equivocal displays in an attempt to reduce equivocality. An ambivalent attitude (or “healthy doubt”) allows for a reasonable equilibrium between trust (or “crediting”) and disbelief (or “discrediting”) towards past experience, and therefore avoids organizations from either becoming ultra-stable or ultra-flexible since “neither form is adaptive for long” [32, p. 217-218].

Weick’s call for a balance between ‘crediting’ and ‘discrediting’ of retained experiences, beliefs and logics, also rejoins Enriquez’s [7] description of work groups that actively thrive in ambiguity-embracing dynamics: that is, work groups that promote both individual emancipation of its members in conjunction with a visible sense of group identity. Such groups, referred to as *differentiated* groups, are characterized by members who respect and tolerate each other’s differences, alongside open dialogue /debate of different opinions and viewpoints. Enabling conditions for such group dynamics include empathy, autonomy, as well as mutual trust and respect between its members [7]. Hence, effective boundary constructions that are simultaneously shaped by the effective sense-making process amongst its members (and vice-versa) require the same enabling conditions.

Weick’s description of sense-making that consistently ‘credits’ or ‘discredits’ its retained experiences and logics rejoins Enriquez’s [7] description of *massified* and *hyper-differentiated*

work group dynamics, respectively. Massified groups are characterized by group identities overpowering individual creativity. Such situations give rise to a ‘groupthink’ that has exaggerated attachments to past and existing knowledge and routines. Open dialogue is rarely tolerated, while fringe members with unique ideas are quickly ostracized. Conditions giving rise to this type of environment include highly authoritarian leaderships, high suspicion amongst group members, little mutual respect, and little requisite variety. Hence, boundary constructions accompanying such dynamics are expected to be ineffective in terms of innovativeness, and are used more for coercive sense-giving (as opposed to mutual sense-making) exercises where power and control predominate [12]. At the other extreme, are hyper-differentiated groups which privilege individual emancipation over group identity. Such groups have no retained collective experiences to draw from for guiding future actions; every idea presented by one member is automatically discredited by another. Dialogue is often aggressive with little mutual respect; and little collective will/vision to implement the most promising ideas. In such situations, one would expect that, at best, boundary constructions (if used at all) are limited to small rivaling factions wanting to ‘outdo’ one another.

2.3.1 Integrating Institutional Context Within the Sensemaking Process

The more recent literature on institutional theory vis-à-vis sense-making allows us to view institutional context as being integrated within the sense-making process.

Early institutional theory, as Scott [27] explains, tended to emphasize the “top-down” models of social influence. Later corrections started to shift away from a monolithic approach by recognizing that boundaries of organizational fields are often vague or weak, while acknowledging that regulative, normative and cultural-cognitive elements may not be aligned [9, 28]. Furthermore, the language started to recognize “bottom-up” modes of influence, to supplement or replace prevailing top-down models [21, 26] in that actors subject to institutional influences can respond in a variety of ways. In fact, as Scott [27] explains, recognizing agency at multiple levels acknowledges the existence of interactions between actors in terms of interpretation,

translation and sense-making. Along these lines, Weick et al [36, p. 417], building upon Hedström and Swedberg’s [10] social mechanisms that link micro-macro levels of analysis, argue that “sense-making can provide micro-mechanisms that link macro states across time through explication of cognitive structures associated with mimetic processes, agency, the mobilization of resistance, alternatives to conformity such as independence, anticonformity, and uniformity, and ways in which ongoing interaction generates the taken for granted”. Similarly, Weber and Glynn [31, p. 1644] explain that Weick’s [33] view of sense-making implies that “institutional context is interwoven with the process rather than constraining it as an external structure” since “institutions not only induce regularity and homogeneity in sense-making through cognitive constraints but also by priming, editing and triggering sensemaking”; in turn, “institutions are continually enacted and accomplished in ongoing sense-making processes”.

By incorporating institutional context within Weick’s sense-making process we can argue that crediting or discrediting of retained logics, assumptions and experience can just as much have to do with the crediting or discrediting of retained norms or rules as with retained personal values, beliefs or experiences. Yet each person’s retained experience, learning path, personal belief, etc. intertwines with retained norms and rules in a unique way such that each person within the enactment and selection processes will make sense of these differently from the next person. Hence, we adhere to the more constructivist view of shared experiences [15] where viewpoints may momentarily, and only partially, intersect as opposed to the more normative view of shared *identical* meanings. And finally, when speaking of enacted environment, constraints are just as much partly of one’s own making as they are objects one reacts to [36, p. 419]. Such micro level actions are, as Weick et al [36, p. 419] state, “small actions with large consequences”.

3.0 Methodology

The research site, given the pseudonym, NorAm Aircraft Engines, is an aircraft engine manufacturer which employs over 5000 people world-wide. Preliminary discussions with a first workgroup (the Engine Operability Development or EOD group) not only confirmed their interest and acceptance to participate, but were involved in regular bi-weekly meetings with another work

group that had not been initially identified (the Engine Component Rig Testing or ECRT group). This second workgroup was also approached, and accepted to participate in the study.

3.1 The EOD and ECRT groups

The EOD group is involved in ensuring the development of adequate engine operability envelopes throughout all phases of engine design and development. EOD group members have a good understanding of the various engine module specialty areas (compressor, combustor and turbine engine modules) as well as how each of these engine modules interact with one another. The group consists of 5 members. All are engineers with 7-25 years experience, and have had prior experiences in either one or more engineering specialty fields such as turbine aerodynamics, compressor aerodynamics, design, and/or general project engineering. One of the principal objectives of the EOD group is to ensure that meaningful engine component operating test data is generated to complement various simulation models used within the engineering specialty groups. Establishing the type of engine test data to be generated is negotiated between the EOD group, the various engineering specialty groups, and the ECRT group; the latter being responsible for the actual generating and integrity of the required engine component test data.

The ECTR group consists of 7 members. Their functional responsibilities include the preparation of component test rigs, their actual running, and the proper collection of test data. The ECTR group consists of one relatively new aerodynamics engineer (2 years prior experience in aero-design), one mechanical engineer with 10 years experience in engine rig design work, and 5 aero-mechanical technicians with 15-25 years experience in coordination and running of the 4 types of engine component test rigs (turbine, compressor, gas generator and flame test).

Both the EOD and ECRT groups interact with one another on a daily and informal basis, and also meet bi-weekly for time periods ranging between 30-60 minutes.

3.2 Data collection

A qualitative interpretative approach was adopted using direct non-participatory observations and interviews. Observation notes were complemented with digital recordings of on-going interactions between individuals (both

in formal and informal settings). Interviews were both semi-structured/formal, as well as ad hoc/informal – the latter type typically following a particular observation of interest.

The units of analysis included: 1) the formal bi-weekly inter-group meetings between EOD and ECRT; 2) the EOD group; 3) the ECRT group. For this paper, we limited ourselves mostly to the first unit of analysis. The period of time investigated was from early February 2007 till early May 2007. The research design criteria is based on *trustworthiness* [14] supported by data collection as per Spradley [29].

4.0. Results

4.1 The bi-weekly inter-group meetings

The first and lasting impression upon assisting the bi-weekly inter-group meetings between EOD and ECRT was the high degree of camaraderie found within each group as well as between both groups; and also extended between the two group managers (Gerry and Frank).

Members, upon entering the meeting room a few minutes early, would often discuss non-work related topics (hockey, renovations, car repairs, etc.). Such socializing also involved a fair degree of good-natured cajoling. On other occasions, members, prior to the start of the meeting, often discussed specific technical issues related to joint project activities. This was often accompanied by the act of sketching a particular view of a rig or engine component that one member was trying to describe, justify or clarify. Throughout such conversations sketches were often drawn and modified in successive superimposing steps by each of the interacting members before finally converging towards a mutually agreed version. During this process, active sense-making was observed, whereby various cues indicating understanding, questioning or disagreement were easily discerned across words such as “Yep”, “Oh really? I thought the chamfer had a smoother profile than that...” and “No, the airfoil cooling hole needs to be drilled at 45 degrees...”. Occasionally, cues provided by on-looking members during the act of sketching would be of an exclamatory nature such as “Oh, ok!”. This indicated that something relatively new had been ‘selected’ and learned, accompanied with ‘self-discrediting’ of prior assumptions. Similar types of sense-making also occurred with the use of pre-existing 2D drawings. Here, existing blueprints were modified (via superimposed iterations between interacting members) with

pen/pencil to once again either express or explain one's own pre-existing perspective (sense-giving), comprehend someone else's perspective (perspective-taking) or construct new perspectives (perspective-making).

Once the formal meeting got underway, the EOD manager (Gerry) usually started by verbally articulating the first item on his status sheet. The status sheet was nothing more than a series of one or two-line descriptions identifying the development engine model/test rig combination in question, the principle tasks being monitored, a completion target date for each of these tasks, and the current status of the task in question. Most of the members had a copy of this same status sheet, while those who had forgotten it were familiar with the tasks they needed to report on (while occasionally looking at their neighbor's copy). Gerry's kick-off words of "QA510 Gas Generator?" would prompt a response by one of the attending members with words such as "We've finish-machined and installed the second compressor stator and the rotating bullet is now being installed. The gas gen. rig should be ready for first shake-down by the middle of next week." Gerry, as well as other members around the table would then note down on their status list, in relation to what was just said. Gerry would then either go onto the next engine model/test rig on his list, or ask a further clarifying question such as:

Gerry: "Are we clear as to what tests Colin needs...do we know which running conditions, and which points we need to measure?"

Jon (*from the ECTR group*): "I spoke to Vincent about this last week, and told him we needed to do some measurements two degrees above and two degrees below the nominal..."

Gerry (*in a patient tone, starts to provide sense-giving*): "Ya, but that's another thing. What I'm talking about here is for the same (*strong emphasis made on this word*) operating point (*pauses*), in pressure ratio and in corrected speed..."

Jon (*provides a cue that he's following Gerry's explanation i.e. perspective-taking*): "Ya..."

Gerry (*continues with sense-giving*): "...and then recording the stabilization time needed for the outlet temperature to reach the ambient temperature."

Jon (*major learning moment - self-discredits his own current assumptions*): "Ah ok! I had understood it was...I'd better get back to Vincent on this - it sounds like I'm going to be a day late after all."

This prompted Gerry, and other members also involved with the item of concern to further modify their respective status lists. Each wrote something similar, yet different enough to address their own respective perspectives.

Whether during the formal meeting or after having reached the final item on the status list, members discussed a variety of technical issues they were jointly working on. As in the pre-meeting informal discussions, these conversations were accompanied by either active sketching from scratch or modification of existing drawings. Members often brought up new points of views which were accompanied by the active listening of others; but once expressed, responses were quick to follow, ranging from further questioning prior to acceptance to further counter-argumentation. Such new points of views were often altered, modified or dropped altogether - yet counter-arguments also went through the same process, often in parallel to the initial argument's transformation. All of this was typically conducted in an atmosphere of mutual respect, trust and appreciation of each others' contributions. Furthermore, sense-giving conducted by various members, including both managers, was principally to guide rather than to coerce. Initial sense-giving by one member was often 'self-discredited' as a result of another member's counterpoint or questioning. Hence, 'healthy doubt' as defined by Weick [35] was often present, and helped ensure a reasonable balance between the 'crediting' and 'discrediting' of beliefs and assumptions.

4.2 A forum for healing temporary strains

The above description is the predominant picture which emerged from aggregate observations as well as individual interviews within both the ECTR and EOD groups. Similar dynamics also seemed to predominate within each of the respective groups themselves. Hence, we are looking at differentiated groups interacting with one another, so as to produce a differentiated inter-group relationship; that is, a certain degree of inter-group identity (which does not overpower the separate group identities) coupled with members that have distinct points of views that are openly expressed within these bi-weekly meetings. Two separate events involving temporary strains between specific members between the two groups allowed us to take a glimpse of what would happen if mutual trust and respect were not present.

The first event involved one member of the EOD group (Jon) who was coordinating an engine/rig project (the QA300/Turbine Rig project) that had particularly aggressive milestones and pressures from an external client. In an attempt to expedite certain tasks, Jon had

tried to influence ECTR members to lower other engine/rig priorities in favor of the QA300. The only problem was he had done this without having specifically discussed this with the ECTR group manager (Frank). Prior to one of the inter-group meetings, Frank had made it clear in a one-on-one meeting with Jon that he hadn't appreciated his actions, and that future issues related to job priorities and resources needed to be discussed up-front with him first. During the inter-group meeting, Frank and Jon had avoided eye contact with one another. Both participated in the usual intermeshing of technical discussions and good-natured cajoling with the other members as the various items on the status list. But when Gerry called out "QA300/Turbine Rig?", Jon's normally active arms remained crossed and inexpressive as he started discussing the project's first-run milestones:

Jon: "...in reality the target is for mid-April, so it's important we complete all things..."

Frank's usually very expressive arms also remained crossed as he interrupts:

Frank (a bit impatient): "Yes, yes..."

Grant, the most senior member in the ECTR group, who has been working closely with Jon, then interjects in a neutral tone,

Grant: "Have we placed the order for the orifice plates?"

Frank (in a somewhat abrupt tone): "No. It's still in the design phase. (Then looking and speaking to Jon) The zinker plate costs 16,000 dollars if we go outside, but will cost a lot less if we do it inside...except that the surface finish requirements are real high..."

The tension between Frank and Jon is easily noticeable across their facial expressions and tightly crossed arms. Grant now interjects in an empathetic tone as he directs his question to Jon:

Grant: "Why is that?"

Frank (jumps in and still abrupt): "Ya, why is that?"

Jon: "In the norms?"

Frank (somewhat less abrupt): "Ya...and when we were looking at that with Dan, I forget the numbers he was giving me, but he was saying..."

Grant interjects once more with an empathetic tone, this time towards Frank:

Grant: "Using a grinder?"

Frank (now visibly more relaxed): "Ya, using a grinder...we'd need a bearing surface finish."

Jon (showing empathy): "Holy cow!"

Although Frank's tone is now more conciliatory, both Frank and Jon's arms have remained

crossed and immobile. There has been no sketching or showing of drawings during the technical discussion in regards to the 'zinker' plate; nor have they updated their respective status lists. But Frank's change in voice tone acts as a cue for others to cajole him:

Frank: "I was speaking to Joe about the CATIA plan..."

Richard (an EOD member who knows Frank quite well – says with a mischievous look): "Ya well, that's what you say...but the truth is he didn't want to speak to you in the first place."

The room explodes in laughter, including Jon.

Frank (trying to control his own laughter): "No. He was ready to speak to me about the frequencies..."

Richard (joking): "Ah, just send him to Poland and that'll solve that..."

Frank (biting his lip, and now trying to sound more serious): "He wanted to speak to me about the frequency spikes we saw last December..."

Tensions had risen and then subsided somewhat, almost like a therapeutic need to get it off their collective chests; and then partially healed or dampened across inter-group member involvement to bring about self-introspection across humor. In a later ad hoc interview that day, Frank tried to put things in perspective by saying, "Sometimes Jon can be a tad zealous in his pursuit to meet milestones...This is the only project he's coordinating, so he has lots of time to focus all his energies on it. He's gradually understanding that I've got 20 or more of these projects that require my group's services and support...He's young and still learning so that's all-right." At the opening of the subsequent inter-group meeting, I found Frank slapping Jon's back in an affectionate manner, as they mischievously needled one another about resource issues. During the QA300 status discussion, Jon had taken out a 2-D drawing and was actively re-modifying it to explain a specific problem pertaining to a turbine inlet duct that needed to be modified. Both Frank and Grant leaned over Jon's sketch and participated in modifying it as they made their own successive contributions to it. At the close of the discussion pertaining to the QA300, Jon, Grant and Frank had also modified their respective status lists.

A second high tension event involved a generic Request for Test (RT) form intended to be used by EOD, ECRT and the rest of the Engineering specialist community. This form, unilaterally initiated by Jon, attempted to identify all the steps involved in the preparation and actual running of a new test rig/engine

combination. Jon had made certain inaccurate assumptions that resulted in the generic form underestimating actual project development times. Upon showing his ‘strawman’ version in an ad hoc meeting, Lloyd (the ECTR group leader) had initially misinterpreted Jon’s draft version as a ‘fait accompli’. Lloyd, who at first refused to look at Jon’s draft generic form, began explaining in a somewhat brusque tone how he felt it was unrealistic to try and account for all the delays that typically occur throughout the development of an engine/test rig. But Jon, across patient explanation, had eventually convinced Lloyd that he was actually looking for Lloyd’s input to try and improve the generic form, and then jointly see if it could in fact serve as a useful guide for creating specific RT’s. Lloyd, seemingly more at ease, then began to look over the form (actively traversing it with his fingers) and proceeded to identify features that needed to be added or improved. In the subsequent EOD/ECTR inter-group meeting, Jon showed Lloyd the modifications he had made to the form according to Lloyd’s earlier request. While they discussed the form, Jon and Lloyd’s fingers simultaneously traversed and pointed to various features of the newly modified form. Lloyd, visibly satisfied, viewed himself as a co-owner and co-creator of the generic RT form, as opposed to being subservient to it.

5.0 Analysis

The different types of mediums and mechanisms used in *helping* to transmit sense (sense-giving) or mutually construct sense (sense-making) within the various inter and intra-group interactions that went beyond verbal articulation included (although are not limited to) the status list, active sketching from scratch, sketching to modify existing 2-D drawings, existing 2-D drawings themselves, and the generic RT form. Some of these ‘objects’ in their static forms such as 2-D drawings and the generic RT form could be classified according to Star and Griesemer [30] as repositories and standardized forms, respectively. And although Bødker [3] acknowledges the activity or mediation that occurs around most of these ‘objects’, they are nevertheless viewed as static representations. Yet in our case, all of the listed ‘objects’ were not only accompanied with some form of visible action on the part of actors, but that it was *during* the dynamic yet transient modifications of these ‘objects’ by these very same actions that sense-making occurred. In our

case study, the status list was actively modified across Gerry’s handwriting, as the discussions advanced from one item to the next. And in conjunction to this dynamic re-construction of the ‘object’ was the updating of everyone’s own sense and perspective of the topic at hand – i.e. we are looking at both imaginary/mental as well as physical de-constructions and re-constructions occurring in tandem. For example, during Gerry and Jon’s exchange in section 4.1, group sense-making (listening members) first occurred in regards to comprehending Jon’s own initial assumptions as to the nature of the test required; while towards the conclusion of the exchange (that is, after Gerry’s own explanation or *sense-giving*), Jon’s own individual sense-making process was seen across the self-discrediting of his own prior assumptions as to how the test was supposed to have been conducted in comparison to Gerry’s explanation. In turn, the group re-adjusted their own sense-making as to which tasks remained to be completed; and modified the status list accordingly.

The sketching from scratch and sketching to modify existing drawings, exemplified more of the same. For example, Frank felt that a certain torque measurement test would involve significant re-modifications of the test rig:

Frank: “...we’ll need to replace the torque-shaft and put a smaller one since the readings we’re trying to pick up are extremely small.”

Richard then draws a schematic sketch (blackboard) while simultaneously explaining how placing a sensor at a specific location avoids the need to make such modifications:

Richard: “We already know the total inertia of the assembly, so by placing a sensor here (*then points with marker at a specific location on torque-shaft*), we should get a good idea of what’s going on...”

Frank then points to a location on Richard’s sketch and draws certain lines in the same vicinity (representing a bearing shroud) along with outgoing arrows representing noise and vibrations; and simultaneously says:

Frank: “...ya but what about the noise and vibrations coming from the bearing shroud?”

While Richard ponders on this, Jon draws an arrow across the bearing shroud while saying:

Jon (draws arrow): “Well, if your main transient vibrations are going this way (*then draws two vertical lines adjacent to the bearing shroud to represent a spacer ring*) you can add a spacer ring damper”.

Jon's input brings a consensus between both Richard and Frank. From a sense-making point of view, Frank's initial idea of changing the torque-shaft was 'discredited' by the combination of Richard and Jon's input, while Richard's follow-on idea of 'no modifications needed' was partially discredited (and therefore, partially 'credited' as well) or modified by Jon's input of 'minor modifications needed'.

The active process of sketching and re-sketching was found (across ad hoc interviews) to be a much more meaningful process for the participants as opposed to simply looking at the end-resultant sketch or construct. Even if the same explanatory words were to be used in the absence of specific motions and line drawing movements (e.g. the portraying of gas flows within a combustion chamber), one would have a less clearer or richer sense of the phenomena being articulated. The line motion acted as a reinforcing cue as well as an aid in focusing attention during the sense-making process. In all of these cases, we are looking at a physical constructions or re-constructions of a phenomena, occurring simultaneously to its verbal articulation. All of these cases involve physical boundary objects being continually transformed by the subject-actors. Even 2D drawings without any visible line markings added to them, were always accompanied by finger movements across various physical features and/or aspects of a physical phenomena the interlocutor wanted to bring an imaginary attention to (e.g. gas flows, stress distributions, a particular hole diameter, etc.). This created imaginary/mental bracketings [33] necessary for constructing mental representations within the minds of the various interacting members. Of course, these boundary objects, were not always in continual movement, but rather in punctuated movement: for example, a line item on the status list could very well remain unchanged on paper, even though verbal (and therefore mental) indicators showed some sort of progress from the previous meeting. This verbal communication attempts to represent changes in progress via the imaginary/mental process of individuals, which at a certain point in time will trigger a visible change to the boundary object (in this case the status list). The same can be said about the generic RT form. It had undergone a flurry of modifications before settling on a satisfactory version. But Lloyd and Jon continued reviewing it every time a new project came along, either to confirm that it was fulfilling its role as a reasonable representation of reality or to be re-

adjusted when a new context warranted it. The movement in this case is the mental re-affirmation or 'discrediting' of the current generic RT document. This mental movement, in turn, may entrain a visible change or re-construction of the physical artifact. Hence, effective boundary objects are either active constructions and re-constructions (as in kinetic energy), or when stationary, are still being energized across the imaginary/mental sense-making processes of interacting actors (as in potential energy). This implies that even in stationary form, their should be very little inertia to get them into physical movement again (that is, to manifest a visible material modification). Hence, we seem to be confirming the postulate deriving from Latour's [13] epistemological insights, in that boundary objects are really more like *boundary constructions*. Furthermore, these constructions are in fact co-constructions, since they involve modifications that are triggered by two or more parties. This, in a sense, echoes Miller's [18] call for effective boundary objects needing to be "co-inventions".

5.1 When boundary constructions cease to be effective

There were two instances when a given boundary construction process had either ceased to function or was initially having difficulty in fulfilling this desired role. In the first, sketching from scratch, references to or modifications to drawings, as well as reference to the status list had literally stopped during moments of antagonistic tensions between two inter-group members (Frank and Jon). Sense-making, had also temporarily dropped to moments of non-exchange and coercion, whereby Frank and Jon's respective perspectives had entrenched themselves into 'self-crediting', all the while trying to mutually 'dis-credit' the other's. Fortunately, this passing tension healed as a result of the underlying mutual trust and respect, as well as past empathies, that had been built over time, which in turn serve as the foundations for a proper balance between inter-group identification/solidarity and individual creativity/initiative [7]. As a result, permanent ruptures were avoided and the three types of boundary objects were eventually re-used for the QA300 at the subsequent inter-group meeting.

In the case of the generic RT form, initial misunderstandings had made Lloyd momentarily assume that Jon was out to coerce, therefore preventing the possibility of co-constructing an

effective boundary construction. Yet prior experience and interactions had built a mutual respect for one another's differences and qualities, as well as tolerance and acceptance of each other's weaknesses. Misunderstandings were worked out, leading to positive dialogue. This energized the RT form to become an effective co-construction between the two actors.

Finally, we argue that the bi-weekly meeting setting provided a forum in which inter-group member interactions built and maintained interpersonal ties, and where people felt at ease to share both technical and personal-social experiences. Such a forum or location is often referred to as *ba* by Nonaka and Konno [20]. Differing ideas were voiced without fear of retributions or ridicule. This came as a result of regular meetings along with a consistent behavior of mutual respect, mutual trust, empathy and tolerance for each other's differences, an openness to differing views and a solid yet varied array of technical experiences (requisite variety). Hence, building on Figure 1-B, we propose that the effective sharing of knowledge occurs as a result of an effective boundary construction/actor-subject interaction, which in turn occurs within a location of shared context (*ba*) where mutual sharing of experiences and ideas across these boundary construction/actor-subject interactions are enabled across mutual trust, mutual respect, empathy, openness to others' differences and ideas, and requisite variety (Figure 2).

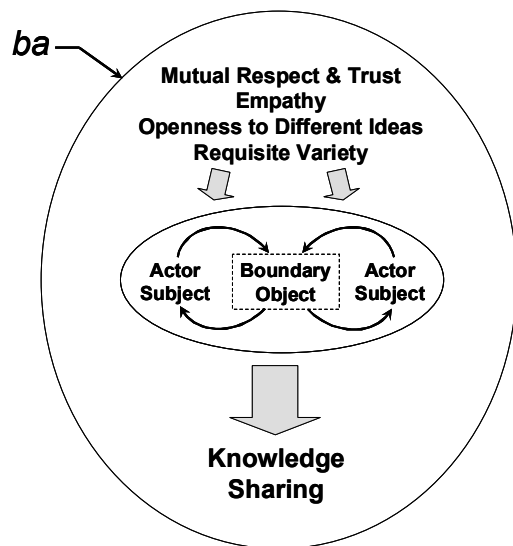


Figure 2. Proposed framework for effective knowledge sharing.

6.0 Summary and conclusions

Empirical results from a qualitative study within an important North American aircraft manufacturing company showed how two interacting workgroups share knowledge across the use of *boundary constructions*. This alternative concept to the more 'traditional' end-resultant boundary object implies an active role on the part of individual actors, and taps into Latour's [13] epistemological insights of mutual transformation, hybridization and inter-reciprocal relationship between the object and subject. This implies that an effective boundary object is in a constant mode of actual and potential transformation resulting from actors continually co-constructing and re-constructing it in both the physical and imaginary sense. In turn, this active co-construction (or boundary construction) serves as a powerful mechanism for enriched sense-making [34] and non-coercive sense-giving.

The alternative epistemological view adopted in this research allows us to shift our basic level of analysis towards asking ourselves which critical enabling conditions allow for effective knowledge sharing via the boundary construction/actor interaction. Effective sharing of knowledge occurs as a result of an effective boundary construction/actor interaction, which in turn occurs within a location or shared context (*ba*) where mutual trust, mutual respect, empathy, openness to others' differences and ideas and requisite variety predominate so as to allow for an open sharing of experiences and ideas. Such an environment is consistent to Enriquez's [7] concept of differentiated work group environments, whereby emancipation of the self co-exists with identification to the other, thereby maintaining a healthy balance between individualism and collective solidarity.

An effective boundary construction/actor interaction ceases to become so, when there is a breakdown in mutual trust, empathy and openness to the other's viewpoint. Consequently, the boundary construction (boundary object) itself ceases to be effective.

We acknowledge that a major limitation of this paper is that it relies on a single case study.

10. References

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