Master Thesis in Applied Information Technology

Design Principles for Convergence of Practices:

An Action Research Study

Per Liljesson, Henrik Haglund

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Abstract

Communities of practice is a conception for describing social aspects of organizational units. Interactions across the boundaries of these are achieved by means of artifacts and practices. The convergence of information artifacts and the community it is intended for is a process of negotiation and adjustment of both. Shared information systems are boundary objects that offer great potential for effective boundary spanning. This paper documents an action research study for development, implementation and evaluation of design principles for enabling the convergence of practices. The results supported that implementation of the principles of transparency and of defragmentation enable the convergence of practices.

Keywords: Communities of Practice, Boundary Spanning, Convergence of Practices, Design Oriented Action Research.

Acknowledgments

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We have not forgotten the significant contribution from our families, who have shown great understanding and have borne the long days and evenings that we have been spent to complete this work.

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1 Introduction

Information artifacts are constitutive of communities of practice which in turn generate information artifacts as a consequence of their practice (Star et al., 2003, Wenger 1998). Information artifacts build communities of practice and communities of practice build information artifacts. Star et al. (2003) label this process of dual buildup *convergence*. In analogy, the opposite is labeled *divergence*.

IT artifacts, or ”those bundles of material and cultural properties packaged in some socially recognizable form such as hardware and/or software” (Orlikowski & Iacono, 2001) are to an increasingly large extent developed to support activities of several communities of practice (Pawlowski et al., 2000, Wenger 1998). An IT artifact in the form of a shared information system acts as a boundary object (Star & Griesmer, 1989, Wenger 1998). Whether a shared system is a simple information repository or an ERP system supporting advanced collaboration processes, the performance of the communities of practice, both viewed as separate or as a collective, is directly dependent on the convergence of the communities of practice and the system. Well-designed boundary objects embody the alignment of perspectives of the communities of practice on each side of the boundaries the objects are to support spanning (Wenger, 1998). This alignment is a product of negotiations between the communities of practice and is yet another form of convergence, *the convergence of practices*.

Action research has its origin in the work of Lewin (1946) and action research methods have been utilized for information systems research since the mid 1970’s (Baskerville & Wood-Harper, 1998). One reason for the popularity of action research in information systems research is that it aims to contribute to both researchers’ and practitioners’ interests by intervention in a situation found problematic by the client organization. This is often the case when it comes to development of an information system for research reasons. The most well known incarnation of the intervention oriented research paradigm is the canonical action research method (Susman & Evered, 1978, Davison et al., 2004). Cole et al. (2005) suggest that for information systems research, the action research paradigm could benefit from adopting the prototyping approach found in the design research paradigm. This approach have been utilized in studies by Henfridsson & Lindgren (2005) and Lindgren et al (2004) and have been labeled *design oriented action research*.

For our master thesis, we were invited to collaborate with Volvo Information Technology (VIT) Tech Watch & Business Innovation, VIT SPRINT (PRoduction INTegration System) Department and Volvo Trucks Corporation’s (VTC) Tuve Plant on a prototype project. The Volvo Group’s aim with the prototype was to evaluate different computer hardware setups and graphical user interfaces for presenting assembly instructions at the Tuve plant with respect to information ergonomics. Today the assembly instructions are distributed to the assembly operators as printouts from the SPRINT system. These printouts are prepared by the production engineers. The assembly instruction functions as a boundary object between the community of practice of assembly operators and the community of practice of production engineers.

The research purpose of this study is to explore how the design of a shared information system can improve the convergence of practices. To examine this and simultaneously contribute to the Volvo Group's objectives we decided to conduct our thesis study as a design oriented action research project. The main research questions for this paper are

1. What properties of the design of a shared information system enable improved convergence of practices?

2. How can these properties be translated into generic design principles for guiding the construction of shared information systems for convergence of practices?

This introduction is followed by an account for the literature study that accompanied the action research study (section 2: Theory). Then we present action research in general and the canonical action research method in particular (section 3: Method). In section 4 we present the research context at Volvo IT and Volvo Trucks and in section 5 we reveal the documentation of the action research cycle we finished during the project. Finally (section 6: Conclusions and section 7: Discussion) we present the conclusions from the study and discuss the contribution to the knowledge of the Volvo Group and of the information systems research domain.

2 Theory

Where otherwise not noted, this section is an account for the theory described in Etienne Wenger's book Communities of Practice (1998).

Etienne Wenger (Web) describes the concept of communities of practice (CoP) on his web page:

> *Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly.*

The concept is applicable to a variety of social groups, e.g., the family, the personnel of an office, the managers of offices in a company, a band of musicians, etc. Though not all communities are CoP, there has to be a shared enterprise and a collective learning process for the term to be relevant. An organization may be viewed as a collective of communities rather than a collective of individuals (Brown & Duguid, 1991). The knowledge of a CoP is embedded in the practice of the community and the conception is valuable to theorize the concept of tacit knowledge. Wenger describes what constitutes the CoP concept as a wide range of explanatory sub-concepts such as *practice, meaning, community, identification, learning, boundary, locality, membership, participation, belonging and negotiability, etc.,* We will give a brief account for these below but we begin with categorizations of knowledge that will be used throughout the text.

2.1 Knowledge

Throughout the literature the concept of knowledge is divided into two general categories, *tacit* and *explicit* (Polanyi, 1967), *know-how* and *know-that* (Ryle, 1949) or *know-how* and *know-what (Brown & Duguid, 1998), sticky* (von Hippel, 1994) and *leaky* (Libeskind, 1996). Tacit knowledge, is something that we "cannot write down" (Polanyi, 1967:) . This is related to experience and know-how and could be explained like know-what put into practice. Explicit, leaky or know-that/what knowledge is knowledge you can write down and is hence easy to distribute. The technical ease of distribution makes it important to knowledge intensive companies to keep track of their leaky knowledge assets. It could be patents that need to be kept secret, or plans for reducing staff numbers. Know-how, or tacit knowledge is embedded in the practice of the knower and this makes it harder to distribute and/or easier to protect.

2.2 Practice

Practice theory focuses on activities in a historical and social context that gives structure and meaning to these (Wenger, 1998). It includes both explicit and tacit elements of language, roles, tools, categorizations and standards, conventions, intuitions, shared world-views and underlying assumptions that are present among the practitioners. Below is a brief account for the concepts that are essential to practice theory.

2.2.1 Meaning

This is a conception for how the individual and collective experience their existence as meaningful. The negotiation of meaning is a continuous and dynamic process that builds on the history of the collective and its members.

2.2.2 Participation

In CoP theory participation is regarded as to share an activity with others. The partaking in a collective enterprise implies a sense of mutuality. The participants have a mutual recognition of themselves in the participants and there is a notion of collective identity. The act of participation shapes the experience of the individual as well as it shapes the community. The members' experience of meaning is shaped by the participation in a broad sense.

2.2.3 Reification

This term means treating an abstraction as if it were an object, e.g., "the evolution has determined that we have less body hair than the apes" as if the evolution were an a priori determinant process instead of a random process of mutations. It is used to contrast participation with the concretization of knowledge into routines, documented processes, abstract tools to convey meaning such as a recipe or a law, etc. It is not unusual that reification comes from without the community with intention to influence the practice of the CoP. To make generalizations and classify entities is to make reifications. A reification is an attempt to concretize a phenomenon in the CoP it is intended for. The attempt of objectification of abstract phenomena can expose ambiguity in experience of meaning and the process of reification of practice includes a great part of negotiation of meaning.

2.2.4 The Duality of Reification and Participation

The concepts of participation and reification are complementary and cannot be regarded in isolation from each other. The law is interpreted by a judge, a cook makes food from a recipe. The potential stiffness of reification could be relieved by participation, the potential informal looseness of participation can be constricted by reification. The two have to be balanced. If important procedures are left unreified, it might lead to ambiguity and difficulties with coordination of the community. If everything is reified and the opportunities for the members of the community to share experiences and interact are limited, then the negotiation of meaning stagnates and the reifications lose their connection to the practice. To avoid misunderstandings though, it should be pointed out that participation is not plain tacit knowledge, it involves actions like conversation, communicating and reflection which is a form of negotiation. Reification is on the other hand not necessarily purely explicit written statements, all kinds of artifacts or rules could be used to reify a conceptual meaning.

2.3 Community

Wenger (1998) associates practice and community through three dimensions, *mutual engagement, a joint enterprise and a shared repertoire.* The CoP includes the members of a specific practice. An agent is more often the member of several CoPs, e.g., the IT professional is a member of the CoP of IT professional and simultaneously of the CoP of his work place.

2.3.1 Mutual Engagement

The meaning of the activities that the participants of the CoP engage in is under constant negotiation. This meaning is relying on the past and the current practice and reifications. The setting for the CoP is an essential factor in the mutual engagement. It could be the common workplace, the band's rehearsal studio (or garage), the family’s joint meals, etc. To understand the social codes and to be included in the community is a prerequisite to mutuality. The mutual engagement in the practice of the CoP is what creates the relationships that glue the community together. There is no implication of similarity of personality or skills of the members of the community, on the contrary, specialization and diversity of skills is what makes the community as a whole a strong unit.

2.3.2 Joint Enterprise

The negotiation of a joint enterprise is another source of community coherence. It is the result of the mutual engagement and the situation of the CoP. At the workplace a joint enterprise may be to earn as big wages as possible, or to work as fast as possible to be able to leave early. Peripheral actors and institutions may try to influence the joint enterprise by efforts designed to control the CoP. The CoP exists in a larger context and the enterprise of this creates limits for how the CoP can pursue and negotiate theirs. By being part of the negotiation of the joint enterprise, the members of the CoP develop relations of mutual accountability. These include what is important and why it is important, what to pay attention to and what to ignore, whether actions and artifacts are suitable to the community and the practice or not, and when they need to be improved. Sometimes the relations of mutual accountability become reified as rules and policies, etc., but those that do not are no less important.

2.3.3 Shared Repertoire

Routines, words, tools, stories, gestures, symbols, classifications, actions, etc., are examples of concepts that the CoP produces or adopt throughout its existence. The concepts have specific meanings to the members and these might be quite different from the labels they get. The shared repertoire reflects a history of the mutual engagement and act as a framework for the negotiation of meaning.

2.4 Learning

There is an important temporal aspect to the existence of a CoP. Wenger describes the temporal aspect as "… a matter of sustaining enough mutual engagement in pursuing a joint enterprise together to share some significant learning" (1998, p 86).

2.4.1 History Embedded in Participation and Reification

Reification and participation converge or diverge in relation to each other over time. This comes from the fact that they exist in parallel and are compared in moments of negotiation of meaning. Besides these moments they are not synchronized. The members of CoPs invest in what they do, in each other and in their shared history while sustaining their practice. The identities of the members become closely related to each other. Furthermore CoPs invest in reification. It can be easier to submit to an established reification than to change it, e.g., the QWERTY keyboard and the resistance to the metric system in the USA (Wenger, 1998, p. 89) .

2.4.2 Histories of Learning

Because the environment is ever changing, the CoP must tune its practice accordingly. The flux of members in a community and the changing context creates a discontinuity in the field of practice. At the same time, the investment made in practice and reification provides stability and resilience to changes.

2.5 Politics

What influences the practices of CoPs can be summarized as cultural, social and symbolic capital (Bourdieu, 1977). Personal authority, nepotism, trust, friendship, ambition, etc., is the means and the driver behind influencing the practices. The politics of reification could be exemplified by laws, policies, statistics, designs, etc. However, the meaning of participative and reificative attempts to influence the practice is always negotiated by the CoP and hence the outcomes of such attempts are always unpredictable.

2.6 Boundaries between Communities of Practice

In the theory of CoP the institutional boundaries do not necessarily coincide with the boundaries between CoPs. The members and nonmembers of a CoP depend on the practice, negotiation of meaning, mutual engagement, joint enterprise, shared repertoire, etc., of the CoP. Two concepts come into focus here, *boundary objects* and *brokering.* These will be explained in further detail below. The boundary object in CoP is viewed as a reification of practice that is designed for communication and collaboration across boundaries of practice, it could be an information artifact such as a form or an information system, or any other reificative object that is designed for boundary spanning purposes. Connecting communities by standardized artifacts is a way to create possibilities for coordination without connection of practice. Brokering practices includes translation between the involved CoPs perspectives and is, in contrast to boundary objects, practice based. Brokering and boundary objects have the same roles in boundary bridging as in the temporal dimension of learning histories, the rigidity of reificative boundary objects can be translated across boundaries of CoPs (instead of across a temporal continuum in the histories of learning) and the looseness of practice can be solidified by reification.

2.6.1 Reificative Connections

The lack of spatiotemporal restrictions makes the boundary object appealing to boundary spanning. Nevertheless, there are inherent limitations in an artifact when it comes to creating a channel for coordination across boundaries. The interpretation of the meaning that the object is designed to convey cannot be predicted and this ambiguity makes it risky to rely on boundary objects alone for boundary spanning. Nevertheless, the rigidity makes it possible to create continuity across boundaries.

2.6.2 Participative Connections

The brokering practices rely on the involvement of individuals to make possible the connection between CoPs. This participational interaction gives opportunity for negotiation of meaning across boundaries. However, there are problems rising from the partiality of participation. A representation of the CoP in form of one or a few members cannot fully represent the CoP. The cognitive limitations make it unlikely that a representational group can keep in mind all aspects of the practice or act as if they were in the context of their practice.

2.6.3 Practice as Connection

Wenger differentiate between three categories of practice-based connections between communities, *boundary practices*, *overlaps* and *peripheries.* Boundary practices occur when some kind of working team is formed with members from several CoPs with the task to establish a connection across the boundaries. If the team is working routinely and is opening a channel for mutual engagement, a practice will probably take shape. Its enterprise is to deal with brokering between practices and these are common in organizations, e.g., cross-functional teams. The boundary practice uses both participation and reification and thus escapes the trap of isolated boundary objects or practices. The risk of the boundary practice is that it may create its own boundary and become disconnected from the practices it is supposed to connect.

The overlapping connection emerges when some members of a CoP are simultaneously members of a CoP that have a joint domain of practice. This could be technical specialists located at a factory site.

Some CoPs open up their boundary to nonmembers. The nonmembers get access to a subset of the practice and can connect with the CoP through their peripheral participation. The position in the periphery is part inside, part outside the boundary and can be a very effective zone for connecting with the environment.

2.7 Boundary Spanning

An organizational unit utilizes the concept of boundary spanning to create a connection between the unit and its environment, between member and nonmembers (Thompson, 1962). The object of boundary spanning could be to expand the knowledge of the community by acquiring knew knowledge form without the boundary or to relate the activities of the community to the environment. When adopting the view of Brown & Duguid (1991), that the organization could be regarded as a collective of CoPs, the mediation and translations between the practices of these need attention of their own.

Aldrich & Herker (1977) identifies two classes of boundary spanning roles, *information processing* and *external representation*. The former is dealing with filtering to avoid an information overload within the boundary, similar to the gatekeeper role as described by Tushman (1977). It is hence a boundary spanning role for managing the incoming information transactions. The latter describes the interface for the interaction with the environment. Typical external representation tasks are matching the environment by managing the resources available through differentiation, etc., to exert influence on elements in the environment to make them fit the organization's demands or to simply watch the environment to look after the organizations position (Aldrich & Herker, 1977). Tushman identifies the *organizational liaison* as an integrating role whose task is to translate between organizational units. This leads us to the boundary practice of brokering.

2.7.1 Brokering

Brokering is the practice of translating across boundaries to facilitate boundary spanning. This practice is often grounded in a membership in multiple practices. The job of a manager, human resource person or IT professional often involves spanning multiple boundaries and coordinating translating between and aligning the perspectives of several communities (Wenger, 1998). Both reificative objects and participation are instruments for brokering practices. Brokering could be conducted by person or incorporated in dynamic objects such as shared information systems (Pawlowski et al., 2000).

2.7.2 Boundary Objects

In 1989 Star & Griesmer coined the term *Boundary Object.*

> *Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites.*
>
> (Star & Griesmer, 1989)

The term is used to describe artifacts that are used for boundary spanning practices. Star & Griesmer discusses four categories of boundary objects,

1. **Repositories**, these are indexed collections of items. These are available for use without the need to negotiate meaning. It can serve multiple perspectives in a modular way.

2. **Ideal Type**, a generalized and possibly vague representation that has its strength in that it is abstract and symbolical. The lack of specialization makes it a 'good enough' road map to convey conceptions across boundaries.

3. **Coincident Boundaries**, objects that have the same boundary but different internal content, e.g., geographic or physical boundaries such as buildings.

4. **Standardized Forms**, these conceptualize work procedures and information that facilitate activities across boundaries.

Organization-wide systems that are designed to support the organizational sub units are good examples of boundary objects. All the above categories could be present in such a system, e.g., an ERP system.

2.7.3 Brokers-in-Practice and Boundary Objects-in-Use

According to Levina & Vaast (2005), the roles of boundary spanners/brokers are often spread out on several individuals to avoid conflicting interests and perspectives. Sometimes boundary spanners emerge that is not designated the role. Levina & Vaast (2005) introduces the terms *nominated boundary spanners* and *boundary spanners-in-practice* to illuminate the difference between the two brokering roles. Levina & Vaast identifies three necessary conditions for an agent to become a boundary spanner-in-practice.

1. The agent needs to become a participant in the practices that is to be connected. To be able to negotiate the relation between the practices and thus at least a peripheral membership of the CoP is necessary.

2. The mandate from the CoPs to negotiate the relations. This could be enhanced by nomination from institutional authority or emerge over time.

3. Personal motivation. Rewards in the shape of economical, symbolic and social capital, e.g., promotion and money, act as driving forces for individuals to engage in boundary spanning. Individual competencies in the practices or in boundary spanning as such are also determinant for who becomes a boundary spanner-in-practice.

In congruence with the line of argument above, the distinction between designated boundary objects and artifacts that emerges as boundary objects are labeled *designated boundary objects* and *boundary objects-in-use.* Examples of designated boundary objects that do not become boundary objects-in-use are the implementation of systems that on the contrary helps to reinforce the boundaries (Goodman & Darr, 1998).

2.8 Convergence of Boundary Objects and CoPs

The incentive for the reification of a practice is to conserve or add structure. When this is done in the form of an artifact it is relevant to discuss the success of the reification in terms of convergence and transparency. The artifact could be considered transparent if it fits and supports the practice in an indiscernible way. This is one of two conceptions of transparency we will utilize throughout our work, a tool is transparent if it is a supporting part in the practice for whom it is designed. The other is the transparency of resources in the aspect of disclosure of information. The convergence of practice and artifact is a prerequisite for transparency. If a tool diverges from its practice it will be obstructive and hence cannot be invisibly usable, transparent. Boundary objects are typical reifications of practice. The complexity of the task of spanning boundaries of several communities makes the design much more difficult. Star et al. (2003) bring forth the more abstract conception of convergence or divergence between *social worlds* and the corresponding *information world* and stresses that the convergence is dependent on the adjustment of both worlds to increase the fit. In the case of convergence between a shared artifact such as a shared information system, and several CoPs, negotiation between the perspectives of the corresponding social worlds and the information world becomes critical for convergence.

2.8.1 Multiple CoPs and Shared Information Systems as Boundary Object

When multiple CoPs are in need of coordinating their practices there need to be overlaps in the information worlds of these. The convergence is accordingly of a different complexity than if considering the boundary between two practices. To achieve transparency for all agents in the joint information world there has to be balanced reifications in form of artifacts and infrastructure.

2.9 Summary

Below is a summary of the central findings from our literature study.

- An organization may be viewed as a collective of CoPs instead of as a collective of individuals.
- A CoP has its own set of conceptions, ways of communication, world view, definition of their enterprise and apprehension of this as meaningful. All these components are under continual negotiation.
- The practice of a CoP unfolds and is being maintained through participation and reification.
- Boundary spanning is the mediation across the boundary between organizational units, or communities of practice.
- Boundary spanning can be facilitated by brokering, e.g., active involvement from individuals or delegations, or by boundary objects.

- Boundary objects facilitate boundary spanning through modularity, abstraction, accommodation or standardization. All these characteristics could be embedded in shared information systems.

- Designated boundary spanners do not necessarily become boundary spanners-in-practice and designated boundary objects do not necessarily become boundary objects-in-use.

- Convergence between social worlds/CoPs and the information worlds/reifications assigned to support them is dependent on the adjustment of both practice and artifact.

- The construction of boundary objects to enable convergence between several CoPs is a complex task that involves mediating between several perspectives.

3 Method

In this section we describe scientific considerations, the course of action, methods and techniques used for the study.

Considering our partaking in the development of the prototype and our intentions to both contribute to the Volvo Group’s knowledge and to conduct academic research for our master thesis project, we decided to base our study on the canonical action research method, as described by Susman & Evered (1978). Furthermore we adopted the design oriented approach to action research as suggested by Cole et al. (2005). This was chosen from a vast range of intervention oriented methods for information systems research (Baskerville & Wood-Harper, 1998) such as Multiview (Avison & Wood-Harper, 1990) and Soft Systems Methodology (Checkland, 1981). The canonical action research method ensures the theoretical rigor and practical relevance. We use the evaluating principles suggested by Davison et al. (2004). Throughout the paper, we will refer to our method as canonical action research and CAR interchangeably.

3.1 Course of Action

Our study consisted of one cycle in the canonical action research method (Susman & Evered, 1978, Davison et al., 2004). In all, five distinctive steps (c.f. figure 1). Each step contains elements of iteration. Particularly the action planning, action taking and evaluation phases were subject to iteration during the prototype run in order to introduce concepts that came out of the continuous evaluation during the prototype run. The arrow from the last to the second step in the figure below points to the iterative character of the action research method in general. In conjunction with the action research study we conducted a literature study to build a theoretical framework and to survey prior research on subjects adjoining ours.

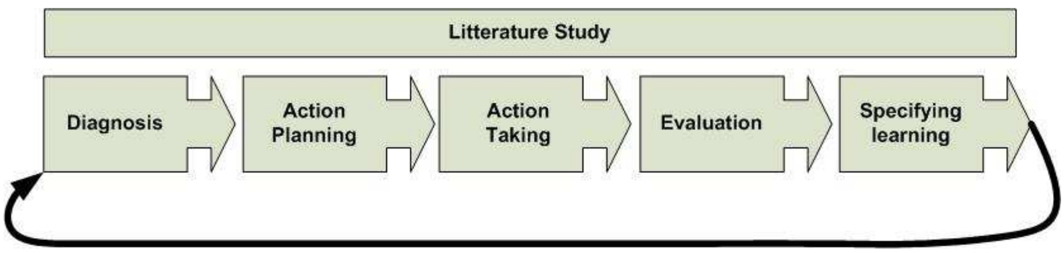

Figure 1: Course of action

3.2 Action research

There are two opposite philosophies of science, i.e. positivism and hermeneutics (Dahlbom & Mathiassen, 1995), also called positivism and social constructionism (Easterby-Smith et al., 2002) or objectivism and subjectivism (Backman, 1998). As Backman's terms imply the difference between the philosophical world views lies in the perspective taken on the research area. Objectivist tradition puts the researcher as a detached observer outside a more or less objective world of observable objects and phenomena. Explanation and prediction are the focuses of the positivist tradition and this should take shape of cause-and-effect connections produced by deduction (Dahlbom & Mathiassen, 1995). Subjectivist tradition does not focus on cause-and-effect relations and testing of hypotheses and states that there is no such thing as an external and objective reality. Hypothesis construction based on data, qualitative analysis, interpretation and that the world is a social construction are themes of subjectivism. Most scientific research methods are not clearly cut positivist or objectivist but falls somewhere in between. Canonical action research is not an exception. The fact that the researcher joins in the problem solving makes it impossible to be objective about the findings. The grounded theory method (Strauss & Corbin, 1998), from which we borrow techniques to a certain extent for data coding, is a typical inductive qualitative method that is used for developing theory from coding and interpreting of data. On the other hand, the experimental setup with evaluation of implementation of design principles reminds of positivist deductive methods.

Action research has its origins in social sciences in the 1940's and the term was first coined in an article written by Kurt Lewin (1946, reproduced in Lewin 1948: 202-3). It grew out of a want to study social groups in organizations while helping them solve problems on their own, or as Curle (1949) put it "… not only to discover facts, but help in altering certain conditions experienced by the community as unsatisfactory". Rapoport (1970) gave one of the most cited definitions of the action research method

"Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework".

The action research method is distinguished by its dual goals and the interventionist approach. The idea behind action research is that to fully understand something you should try to change it (Easterby-Smith et al., 2002). The change processes of modern organizations are closely linked to the development of information systems (Baskerville & Pries-Heje, 1999). Whether the information systems development is the driving force behind a change process or driven by a change process in the organization, the alignment of organizational architecture to the architecture in the information systems is critical for the success of the organization (Magoulas & Pessi, 1998). The action research method is a hence a good tool to understand the link between organizational change and information systems development because of the intervening approach.

3.3 Canonical Action Research Method (CAR)

Action research is thus a method for analyzing an organizational problem situation, introducing change that should tackle the problem and evaluate its effects. All in collaboration with members of the organization and the desired outcome of an action research study is a contribution to both academia and practitioners. One problem with action research is a lack of generality in the results. They are often tied to the specific organizational context and the specific problem situation. To remedy this, Baskerville & Pries-Heje (1998) suggests the inclusion of techniques for theory formulation used in qualitative research known as Grounded Theory (Strauss & Corbin, 1998). From its original two-phase research cycle, consisting of a diagnostic phase and an action phase the method has been updated with more structure. Susman & Evered (1978) revised the method and identified five distinct steps per cycle (c. f. figure 2). These should take place in a research environment that is established first, what Rapoport (1970) called "a mutually acceptable ethical framework.". The five steps are named Diagnosing, Action Planning, Action Taking, Evaluating and Specifying Learning. The steps are not supposed to be executed in a strict sequence. Instead iteration over one or more steps is suggested to refine the theory, concepts and data in a learning process. The collaboration between researchers in each phase might vary from project to project and the degree of collaboration is a parameter for categorizing action research projects. Chein et al. (1948) use the label *diagnostic* for research where researcher only collaborates in the data collecting for presentation to the collaborators, *empirical* when only evaluating, *participating* when diagnosing and planning action and *experimental* when all steps are carried out in collaboration with the research environment. Furthermore, there is an abundance of techniques for collecting data for the phases. This is primarily done during diagnosing and evaluating and could be done by interviews, observations or questionnaires.

The variant of action research we adopted for our study could be labeled *design oriented action research*. It distinguishes itself through its intention to develop and evaluate design principles for information systems design through prototyping. The works of Henfridsson & Lindgren (2005) and Lindgren et al (2004) have previously developed and utilized design oriented adaptions of action research methods such as grounded action research (Baskerville & Pries-Heje, 1999) and CAR respectively.

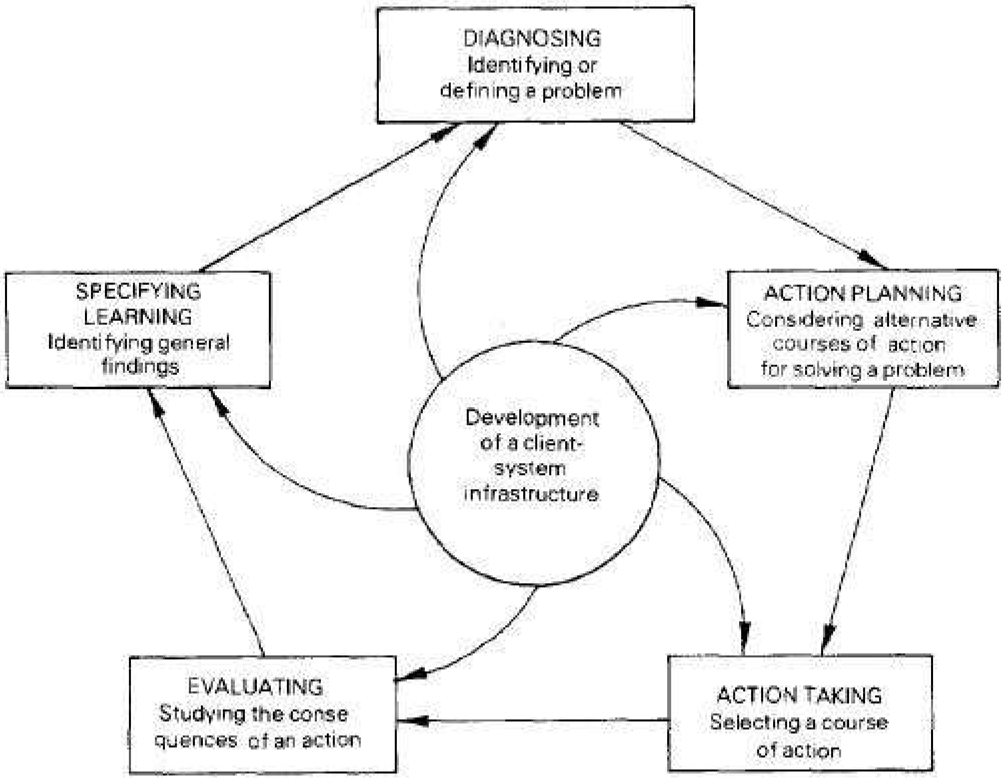

Figure 2: The Action Research Cycle (source Susman & Evered (1978))

3.3.1 Diagnosing

During the diagnosing phase, the task is to penetrate the organizational context and the causes that are driving the desire for change. This should produce some initial categories or themes that will be evaluated through data collection and coding and help build an initial theoretical framework for the other phases.

3.3.2 Action Planning

Action planning is the specification of suitable actions that is expected to resolve the problems underlying the wish for change. The development of the proposed actions should be guided by the theoretical framework from the diagnosing phase, with regard to the target organizational state. The collaboration between the researcher and practitioner is important for a successful design of possible change actions.

3.3.3 Action Taking

The action taking is the final step in the technical design of the change action. During this phase the most appropriate suggestion from the previous step is chosen for implementation.

3.3.4 Evaluating

The researchers and practitioners implement the change, analyze the effects and evaluate these with regard to the theoretical framework. A holistic stance should be taken to consider whether it is the applied actions alone that have caused the changes to the organizational state or if it is changed by means of other events in the context.

3.3.5 Specifying Learning

Although the action research process is a continuous learning process, there must be an evaluation point with regard to what can be considered the general findings from the cycle. This should again be verified against the theoretical framework, which itself should be scrutinized and subject to adjustment. This phase is reminiscent of a traditional analysis section but here it should be reported what knowledge has been gained and whether to proceed with another cycle. These are elements from traditional conclusions and discussion sections.

3.4 CAR Evaluation Principles

Davison et al. (2004) suggest five principles for confirmation of relevance and rigor when conducting canonical action research.

1. Researcher-Client Agreement (RCA)
2. Cyclical Process Model (CPM)
3. Theory
4. Change through action
5. Learning through reflection

This builds on Susman & Evered’s work but introduces a more explicit framework of criteria to facilitate comparability and standards for CAR. The development of the principles may be regarded as a response to criticism towards action research, but the framework could act as a means for a more coincident view of action research in the IS disciplines as such. In appendix 2 we give an account for the framework of principles, associated criteria and how our study met these.

3.5 Data Collection and Analysis

We used several approaches for collecting and analyzing empirical data. Which techniques were utilized depended on the situation. During the first part of the diagnosing phase, for example, we used several, short interviews and participant observation. When our focus narrowed, we started to map processes and dependencies and this was based on in-depth interviews and longer observations.

When analyzing the data from the diagnosing phase, we borrowed techniques from grounded theory (Strauss & Corbin, 1998). We must stress that our study in no way was adopting the grounded theory approach. This presupposes that there is no guiding background theory in the study, but that theory emerges from the data. The emerging theory is then verified towards data again and adjusted until there is no change in the theory.

Grounded Theory data analysis techniques consist of three types of coding methods, *open*, *axial* and *selective*. The coding process is continuously under refinement during the iterations over the data. This is a deduction process that aims at exploring concepts from data and an induction process when verifying the concepts on the data. Since we did not utilize selective coding its details will not be explained.

3.5.1 Open Coding

The raw data is analyzed and emerging distinctive phenomena is labeled as concepts. These are grouped, classified and abstracted to categories and subcategories. Categories and subcategories are associated with properties and dimensions. Dimensions are properties that are located somewhere on a range or some kind of continuum, e.g., a range between “very positive” and “very negative” in an attitude survey.

3.5.2 Axial Coding

During the axial coding procedure connections and cross links between categories and subcategories are identified. Subcategories may relate to several main categories of classified phenomena and this is determined by comparing dimensions and properties. These conceptual interpretations, categorizations and linkages of the data are a part of a deductive process that demands that the perspective of the researcher is clearly stated.

4 Research Setting

The primary location for our survey was the truck assembly process at VTC's manufacturing plant in Tuve on the fringes of Göteborg. In this section we give a description of the client organization and the initiation of the action research study.

4.1 The Volvo Group

Renault Trucks, Mack and Volvo Trucks are the Volvo Group’s brands for its production of trucks. Together these make the Volvo Group the largest producer of trucks in Europe and second largest worldwide. Volvo Trucks is producing medium heavy to heavy trucks and have several factories around the globe, for example in Sweden, Belgium, France, USA and Brazil. The Volvo Group has a bundle of companies in the vehicle manufacturing business: Volvo Buses, Volvo Aero, Volvo Penta (Marine engines), Volvo Construction Equipment, Volvo Powertrain amongst others and VIT serves as an internal IT services provider. The Volvo group no longer makes cars since the car manufacturing division was sold to Ford in 1999. The Volvo trademark is protected and maintained through a company jointly owned by both Volvo Cars Corporation and The Volvo Group.

4.2 Assembly process structure at the VTC Tuve Plant

The truck assembly process at the Tuve plant is divided into two main production flows and several sub-flows. The main flows are in turn divided into segments which each focus on a specific assembly area. The production vehicles are based on 20 base models but in the end, 70% of the ca 34,000 vehicles produced each year has special features. This high degree of specialization frequently makes the load on the regular production flow too heavy and special attention is required. This is dealt with at the special variant stations (at the motor line it is labeled the EXOP station) where parts present on less than 30% of the vehicles are assembled. There are even more specialized assemblies that are too complicated to be handled at the variant stations, like specially dimensioned fuel tanks or heat insulated fuel systems. These assemblies are done by the non-stationary S-team. This team has their own pre-assembly shop and task coordinator. It operates beside the operators on the regular flow, trying to minimize the interference from their work on the regular flow by splicing in their work where it creates a minimum of interference. If the vehicle is too complicated to be built at the regular flow altogether it can be built in the prototype shop. Custom adaptations such as special loading platforms or cranes are assembled at the customer adaptation shop (CA). Since our focus is the communication of assembly instructions to the assembly operators, we have omitted the logistics of parts share of the assembly process and how information regarding this influences the information environment of the assembly operators.

4.2.1 Assembly Information Environment at the VTC Tuve Plant

The processes behind the assembly instructions today are tightly connected to the parts supply of the assembly flows. The synchronization of parts from internal companies as well as external subcontractors is limiting the speed at which updates of parts logistics and instructions can be performed. The process at which the instructions and parts are tied to the orders is called the Definitive Run. It takes place three weeks before the assembly it is designed for. The SPRINT system is the tool the production engineers use to connect the right parts and instructions to each chassis (the SPRINT system replaced the MUL (Monterings Under Lag) system in 2005 and the personnel use the old term MUL for the SPRINT-generated printouts of assembly instructions. In our study, SPRINT and MUL are interchangeable). The production engineer can add a description to each core instruction and determine whether bold style or italics should be utilized to highlight text. Furthermore the production engineer sets the time each assembly requires, this is determined from the standard tariff. The assembly sequence is set by the production engineer. The SPRINT system then suggests a division of the assemblies among the stations at the segments of the assembly line and orders for parts are sent to suppliers, this is called the breakdown process. After this, the electronic documents that are generated are sent to an external printing company that delivers printouts to the plant for internal distribution. Each vehicle generates 325 sheets of instructions on average, and the cost of the printing alone (distribution costs excluded) is ca 7 million SEK. The prototype team had estimated that acquisition of PC terminals to all assembly stations would not exceed the costs for the printing alone.

4.2.2 Deviations Handling

Deviations are logged in the internal production quality system QULIS (QUaLity Information System). This is done by quality support personnel along the assembly line segments, or by the control operator at the control zone at the end of each segment. When a deviation is discovered by an operator he gives a short description on a form that follows the vehicle throughout the assembly line. When the vehicle reaches the control zone the control operator receives the deviations form and takes proper action, normally he logs the deviation in QULIS (figure 3).

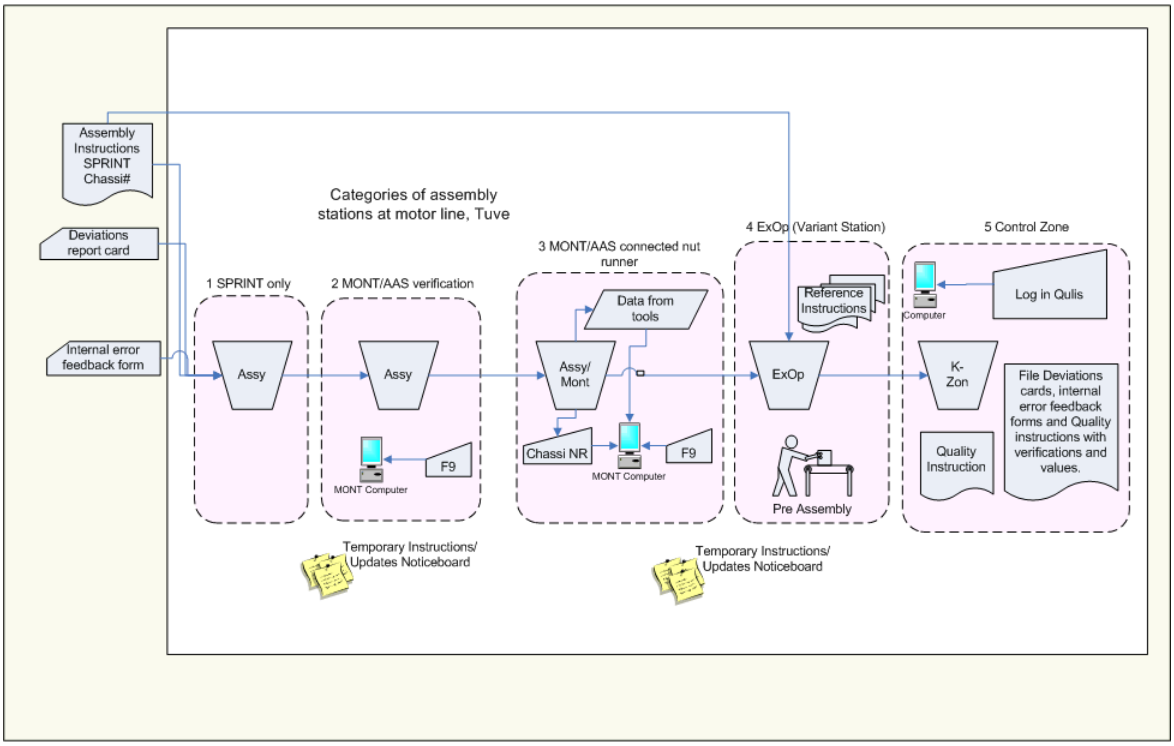

Figure 3: Information environment at the motor assembly line

An issue in QULIS is treated in six steps: data collection, temporary measures, root cause analysis, permanent measures, results follow-up and completion. It is possible to add comments, documents and files, e.g., pictures to each step. The responsibility for each issue is specified in the system log as an issue owner and issue assigner (c.f. appendix 1). The plan at VTC is that MONT, SPRINT and QULIS should be core systems at all VTC plants worldwide. The quality support personnel at each segment should give individual feedback to the individual assembly operator when a mistake is discovered. To be able to trace who have executed the assembly, each chassis comes with an internal error feedback form for each segment upon which the assembly operator puts his personal stamp at each station. The control operator has a combined checklist/form called quality instruction for each chassis and control zone which he stamps and fills out. The internal error feedback form and the quality instruction form are saved locally for two to three weeks and are then disposed of.

4.3 Action Research Project Initiation

In all, VIT had three major incentives for the prototype, cost reduction, assembly assurance and of course environmental concern. As aforementioned, printing costs yearly exceed 7 million SEK at the Tuve plant alone. The cost of distributing and handling the printouts is difficult to measure precisely but there is a potential for great reduction of costs when distributing the instructions digitally. Assembly assurance is a concept for securing individual assemblies, for example that certain nuts are tightened to a certain torque or that the right parts are married, e.g., that the right gear box is assembled to a specific motor. Some assembly stations today have PC terminals with computer-controlled nut drivers. By using these computer-controlled nut drivers it is verified that the right number of nuts are tightened and at the right torque. This system is called MONT (unknown acronym) and is present at some stations at the motor sub-flow and the initial part of the chassis assembly. The axle sub-flow also has the MONT system installed, but here the MONT PC is mounted on the carrier that transports the axle between stations.

As for the environmental concern it deserves to be mentioned that the on average 325 pages of instructions that each truck generates, amounts to 2500 trees that need to be cut down each year. Not to mention the environmental strain that comes from producing, printing and distributing all this paper.

This was the background for VIT to initiate the prototype project called “Paperless Manufacturing”. The company’s objective for the project was to create business cases for different implementations of hardware and software to replace the paper instructions. To bring in new ideas and outside perspectives they contacted the IT University of Göteborg to approach master thesis students for a collaboration project. We saw an opportunity for an action research project and contacted VIT. A prototype team was formed. The prototype team consisted of a prototype leader from VIT Tech Watch & Business Innovation, a systems developer from VIT at Volvo Powertrain Skövde, the SPRINT superuser at the VTC Tuve plant and us Master Thesis students.

The expectations on our work from Volvo came in form of suggestions. These could range from programming of graphical user interfaces to modeling the necessary changes of the data models that would be necessary to integrate the SPRINT production system to a computerized assembly instructions environment. However, at an early stage we identified a problem area of less technical character that the assembly operators did not perceive the instructions meaningful and supportive to their work. Furthermore our survey soon pointed to that the communication between the operators and the clerical workers that prepared the assembly instructions, the production engineers, was insufficient. This gap between the two CoPs was due to a lack of the negotiation of the assembly instructions information environment in general. We thought this gap needed to be addressed for taking the full advantage of the migration from paper based to computerized instructions display. So our initial focus for the project became to develop, implement and evaluate design implications necessary for a system to be perceived as meaningful and supportive to both operators and production engineers.

As members of the prototype team, we had opportunities for studying the effects of our suggestions in two contexts in the Volvo Group organization:

1. **The Prototype team** In the frequent meetings with the prototype leader, the SPRINT super user and the system engineer, we could try out concepts that emerged out of our survey work. This became our arena for exploring feasibility of the concepts mentioned above to organizational expectations on the outcome of the prototype.

2. **The Volvo Trucks plant in Tuve** The prototype was setup at the Tuve plant and we got an opportunity to demonstrate our input to the prototype to both white collar and blue collar workers at the plant.

Although it would have been interesting to study the effects of our work in the prototype team on the outcomes of the team, we decided to focus on the impact of the prototype on the organization in Tuve.

5 Empirical Results

In this section we give a thorough report of the results from each step in the action research cycle we realized during the master thesis project.

5.1 Data Sources

During the 16 weeks of the study we completed one cycle of the canonical action research method. Data was collected through participant observations at the plant in an interrupted involvement fashion, separate in-depth semi-structured interviews with personnel and at collaborative workshops with both practitioners and researchers.

Table 1: Data sources for first CAR cycle	
CAR Phase	***Data sources***
1. Diagnosing	▪ Literature review ▪ Several days of Participant observation ▪ 5 semi-structured interviews (Operators & Production engineers) ▪ 2 collaborative workshops
2. Action Planning	▪ Literature review ▪ 2 Semi structured interviews (QULIS Administrators) ▪ Collaborative workshop
3. Action Taking	▪ Literature review ▪ Information meeting ▪ Several days of Participant observation ▪ Collaborative workshop
4. Evaluating	▪ Literature review ▪ 6 semi-structured interviews (Operators) ▪ Collaborative workshop
5. Specifying Learning	▪ Documentation generated in previous steps

Table 1: Data sources for first CAR cycle

5.2 Diagnosing

The diagnosing phase started with three days of observation where we simply walked around the factory and acquainted us with the different assembly segments to get a feel for how the assembly was done. During these three days we also got the opportunity interview four assembly operators from different parts of the assembly line. The interviews were conducted together with the prototype leader and the SPRINT super user, who had selected the respondents “because of their knowledge of the processes and their interest in information technology as a problem solver”. It appeared that there were perceived problems with the contents of the instructions that we had not anticipated. One theme that kept reoccurring during the interviews was the lack of accuracy in the instructions. Furthermore, if an assembly operator endeavored to report a minor error in the instructions the anticipated time for correction of the error was expected to be six months or more, if corrected at all. These problems appeared to have a long history and reduced the assembly operators’ perceived meaning of the instructions and therefore lessened their motivation to look at them. Instead, to a very large extent, they assembled as they “knew how to” from prior experience. Finding the problems mentioned above pointed to the importance of building up the assembly operators’ perception of the instruction as being useful to their practice. Theoretical concepts like Communities of Practice (and how meaning is created in these), Boundary Spanning practices, Boundary Objects seemed to be applicable to the research area and we included these in our literature study. The interviews broadened our understanding of the problem area and we started to direct our focus towards the communication surrounding the construction and utilization of the instructions.

The second week we visited the plant without guidance to further explore the problem setting and conduct spontaneous short interviews with the assembly operators in their working context. We observed that mostly the operators did not look at the instructions more than once or twice during the thirteen minutes at hand at each station. This led us to the conclusion that there was a significant amount of redundant information in the printed assembly instructions since each station receives on average 3 pages of instructions. We also concluded that this was due to absence of collaborative efforts to create instructions that were adjusted to the practice or negotiation of meaning for the boundary object. Hence, the instructions were to be categorized as a designated boundary object that had not become a boundary object-in-use. We surveyed the different information environments of the segments and decided to investigate how information to the S-team was handled. The S-team information environment appeared to be the most complex we could identify at the plant. The work of the S-team furthermore relied heavily on an internal standardization of assemblies and a significant part of their knowledge was not reified but purely tacit. A deeper look into the S-team was expected to reveal information that could be useful at other parts of the assembly plant, regarding that the bulk of their job was to deal with tasks that deviated from standard assembly operations.

Thursday the third week the prototype team held a workshop where stakeholders from all layers of the assembly process participated (assembly operators from a variety of segments, production engineers from CA and the S-team), a committee that surveyed needs for standardization of operator training, as well as researchers from Chalmers and Volvo Technology involved in the EU-project ”My Car”. The purpose of the workshop was to inform all the stakeholders of the project and to try to capture the demands and expectations of the stakeholders. At the workshop, the systems developer from VIT Powertrain presented a system for displaying digital assembly instructions that they have implemented at Volvo Powertrain Skövde and partly at VTC in Tuve (MONT). It was decided that we would use this system as a basis for our prototype. At the workshop we presented our preliminary findings and declared our intention to focus on how the system can be implemented to simplify the communication of deviations related to the instruction. We received much positive feedback and opinions from researchers and practitioners which strengthened our belief in the validity of our working concept.

The workshop was followed by several meetings and interviews with personnel from different areas of the assembly process such as assembly operators, special assemblies’ group coordinators and production engineers. Meetings and interviews were either recorded or carefully noted in mind maps. The material gathered from workshops, meetings and interviews where then analyzed by focusing on the use of and updating of the instructions (c.f. table 2). Theoretical concepts were mapped to the emerging categories (c.f. table 2).

The substantial amount of tacit knowledge of the S-team and the complex logistics associated with their work made it difficult to accomplish a change that could affect their organization, due to our time limits for the project. Furthermore we questioned whether findings from the S-team would be applicable for the regular assembly line since the S-team is specialized in dealing with deviations. Instead we brought the experience from our work with their situation along when redirecting our focus to the motor assembly line. Computers were already present at some stations at the motor line, so the implementation would not have to force the obstruction of insufficient computer experience. The motor assembly line has the division of work that is typical of a segment of the line throughout the Tuve plant. The special assemblies at the motor line are somewhat limited in frequency, but the EXOP variant station deals with the pre-specified set of variants.

During the next stage of the diagnosing phase we therefore concentrated on interviewing personnel from the motor assembly line. From these interviews no new categories seemed to emerge but more data that bested our categories were collected.

The core problem dimensions that we found during diagnosing are summarized in table 2. Furthermore, we show how the problem dimensions are linked to our theoretical concepts. A detailed review of the results from the diagnosing phase is given below.

Table 3 Results from diagnosing phase				
Code	**Category**	**Argument**	**Dimensions**	**Theoretical concepts**
A1	Information Infrastructure	▪ Communication of deviations is handled through a chain of people, "Chinese whispers". ▪ It is not always that all information you need to assemble correctly can be found in the instruction. ▪ Dispersed information processes	Fragmentation	▪ *Boundary spanning practices*, the unstructured communication processes regarding the deviations reporting stem from the unspecified boundary spanning roles. ▪ *Boundary objects-in-use*, the scattered and outdated set of boundary objects needs structured processes.
A2	Gap between the community of production engineers and the community of assembly operators	▪ Unclear responsibilities for issues regarding deviations. Lack of traceability of deviations issues. ▪ Operators do not have sufficient knowledge of the deviations handling process to give precise reports –"The tube is not long enough", Differences in language ▪ When errors in the instruction are reported operators are often left with the perception that noting is done to correct these errors. Differences in conceptions.	Opacity	▪ The absence of boundary spanning practices and boundary objects with convergence is obvious. Reifications are not negotiated. ▪ There is a clear deficiency of understanding across the boundary.
A3	Accuracy	▪ Instructions are not always up to date. ▪ Instructions often contain errors. ▪ Sometimes certain assemblies are not properly supported by instructional text or picture	Fragmentation	▪ The frequent error in the instructions and the long period before correction is an effect of the lack of cooperation around the processes. This requires boundary spanning practices and well negotiated boundary objects to enable efficient information processing over several boundaries (c.f. figure 4).
A4	Amount of information	▪ The amount of information an operator need to assemble correctly is highly individual. ▪ A lot of unnecessary information is presented in the instruction. Operators often skip parts of the instruction because they "know" that the information is superfluous.	Fragmentation & opacity	▪ The content of the instructions is redundant and has not been negotiated. There is a divergence between the reification (instructions) and the practice (assembly).

Table 2: Results from diagnosing phase

5.2.1 Information infrastructure

During the diagnosing phase it became obvious that the handling of deviations was extremely complex and resource intensive. We tried to capture the complexity in a schematic way (c.f. appendix 5). The systems and processes seem to be constructed in an ad-hoc manner, which makes the information environment severely fragmented.

There are three occurrences that can cause changes to the instructions, either the customer wants something different or the quality assurance process reports a problem with a certain assembly so that the instruction needs to be changed to fix the problem. The third possible cause of changes to the instructions is that the operators report something to be wrong with the instruction. When detecting an error in the assembly instructions, the operator is supposed to rip out the page from the sheaf, mark and comment on the error and put the sheet in an assigned pigeonhole. This process is not reliable and it is not unusual that less urgent errors fall out of the production engineers' focus. This decreases the assembly operators' incentive to report errors in the instructions.

"When I was still learning... And all the time when you asked about something… - you should read the MUL [instructions]. You can find it in MUL. So I read in MUL and it was wrong! … Where is the security that I assemble the right way?

So it started out with that I marked errors, pulled out the page and saved a small pile of papers. Then I turned them in on a break but then they were lost. … Probably nothing will ever happen because as everyone says: It doesn't matter, they [production engineers] don't change anything anyway and it takes such a long time. But I did that for a while, marked errors… but ... that didn't turn out well.
…you feel so far from… like… the center of attention. … there are too many steps… to do something about it."

(assembly operator)

The uncertainty in the instructions makes them an inadequate tool for the CoP of assembly operators to perform their work. In many cases they are reduced to work from the collective body of experience amongst their peers.

Late changes are communicated through temporary instructions posted on notice boards that are not always in the immediate vicinity of the assembly area. These temporary instructions are used until the change is visible in the SPRINT printouts or until the entire order has been processed.

However, there are times when temporary instructions are not enough. As stated by a production engineer

"If I have added the wrong part to an order then I must go down to the factory floor and manually sort out the instructions that are faulty and correct them.

Otherwise there is a risk that many people will have done a lot of unnecessary work".

This of course adds to the plethora of ways that changes are communicated.

With all the custom assembly information it is extremely important that the instructions are correct and that the assembly operators follow them. However, in many situations the information is proved incorrect and the operators prefer carrying out the assemblies based on their knowledge, both that of the individual and that of the team. Since the operator must consult the temporary instructions to really assess the validity of the instruction it adds to the preference of assembling from knowledge rather than from the instruction. As stated by an operator.

"I don't really read the instruction I know what to look for, I know what can vary".

Similar statements where made by many operators. The problem with this kind of knowledge is that it based on historical data and is thereby resistant to change since the new knowledge that can be gained by reading the full instruction is never introduced.

During this survey it became clear that the gap between the production engineers that put together the assembly instructions in the SPRINT system, and the assembly operators was vast throughout the entire factory. This was part due to the processes and part to resources and attitudes. When the operators find a deviation in the SPRINT printouts they are supposed to rip out the page and mark the deviation, write down comments and hand it to their Group Coordinator (GO) or Technical Adviser (TA). They in turn will bring the page to the production engineers and they in turn will take necessary actions to correct the problem (figure 4). The production engineers have to decide whether the solution to the problem requires changes in the instructions alone, or changes to the construction as such. The construction adjustments are handled via the *PROTUS F* (unknown acronym) system that is a system for handling change issues regarding the construction. When the constructor has chosen the appropriate update to the construction, he makes the corresponding change in the *KOLA* (unknown acronym) system that feeds the SPRINT system.

There are a number of problems with this process. The production engineers often have difficulties understanding the problems that the operators reported and it is a cumbersome job to find out who has reported what to further survey the details of the reported problem. The gap between the community of assembly operators and the community of production engineers is supposed to be handled by the designated boundary spanners, i.e., the GO and the TA. In effect, these are members of the community of assembly operators and do not have the sufficient peripheral participation in the community of production engineers. The GO and TA roles in the communication between the two communities are limited to pass on information. Hence, the spanning of the boundary is ineffective regarding the communication of deviations reports. This could be exemplified by the quotation below:

”Like when I get a report saying the tube is to short. That doesn’t help me! I need to know how much too short it was and how long is the tube when measured”.
(Production engineer)

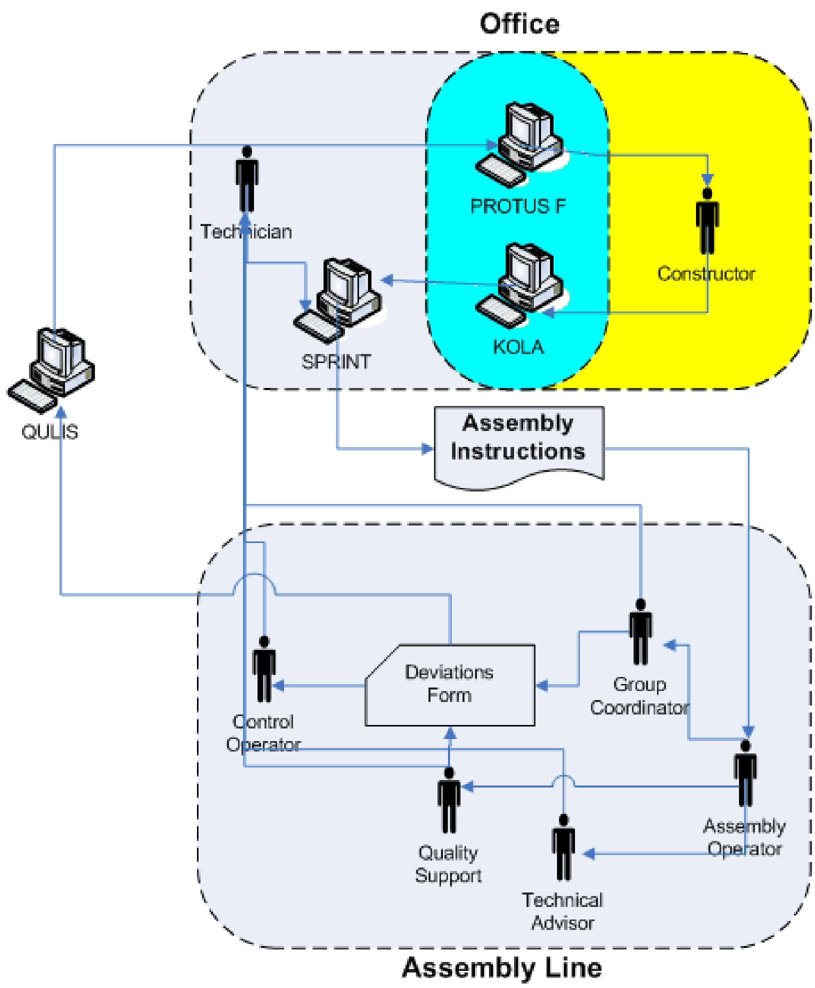

Figure 4: Actors systems and artifact in the assembly information environment

To further survey this problem the production engineer needs to get more precise information from the assembly line. This could be achieved by contacting the GO or TA to ask him to retrieve further information from the operator, or by going down to the assembly line and look up the situation in person. The boundary spanning layer of GOs and TAs in the process described adds a processing step to the communication chain. This opens for the possibility of misinterpretation. In addition, the efficiency of the process is relying on the synchronization of the all the involved participants, which makes it vulnerable to lacking engagement and resources at each part of the chain.

5.2.2 Gap between communities

During the diagnosing phase we met many operators that stated that they felt that there was no use in reporting errors for corrections because they felt that they were never corrected.

"One time we plastered the production engineers cubical with faulty instructions… but nothing happened".

(Operator)

The technical department on the other hand stated that they correct 80% of the errors that they receive. This gap in conception is partly explained by the fact that the operators have no control over where in the correctional process their reported error is and whether their report is actually going to lead to a correction. Sometimes the errors reported are due to personal preference rather than being a real error and then the production engineer will take no action. The lack of communication between the two communities surrounding these matters makes it difficult for the operators to see the differences between the errors that they report that do become corrected and the ones that do not. The joint negotiation of meaning of the boundary object (error report) is absent.

The fact that the assembly operators do not get any feedback or knowledge of what happens to their report makes them feel as if it does not matter what they report. Deviations that get attention from the production engineers and that have to be attended immediately generate a temporary instruction on a notice board along the line. The time to the permanent change of instructions can then be as long as half a year, or longer.

Long before these changes take effect the assembly operators have already adjusted their practice according to the temporary instructions. Since they are used to the instruction being incorrect they have since long stopped looking at it and therefore the actual effect of their report, i.e., the change of instructions, often pass unnoticed.

Another thing that contributes to this gap in conceptions is that errors that are not critical to construction, e.g., bolt lengths, are put at the bottom of the production engineer's to-do-list which further delays the correctional process and undermines the importance of reading the instruction.

This gap in conceptions is further reinforced by the structure in the company illustrated by the following statement.

"I can just say that the production engineers hardly get any reports on assembly instruction-errors (MUL-errors) anymore. They see it as a success!
- We have corrected all the MUL-errors.
I say this is not the case but that is what the KPI's [Key Performance Indicators] *are showing… It is a bit scary that when you read the MUL there are errors. But we pat ourselves on the back saying we are good at this! No wonder we think that we are when we don't receive any error reports".*

(SPRINT superuser)

The production engineers believe that they have corrected all important errors and are happy with that and the operators have learnt to live with the minor errors. There are no forces in play within the organization to budge that equilibrium and this enhances the divergence between the communities. We found that the gap between the communities was a product of the process of handling deviations and errors being opaque. It prevents the communities from developing a common language. It also prevents them from bridging their difference in conceptions.

During our survey we could not find any boundary spanners-in-practice. The production engineers seldom leave their office to visit the assembly line and the assembly operators seldom visit the office. The communication between the two CoPs is carried out through the boundary objects of varying degree of standardization. The SPRINT printout is a highly standardized document with little room for input from the production engineer. The meaning of the document is not continually negotiated across the boundaries and the meaning of it is negotiated within each separate practice. This makes for a great deal of uncertainty of the conveyed meaning. The QULIS system is to a large extent a boundary object-in-practice, but it is not used widely in the communities with connection to the assembly line. It is used by the quality support personnel and control zone operators. When we browsed the finished issues list in QULIS at the Tuve plant we found some issues where the production engineer had aided in finding and attending the cause of the error. These were however from the evening shift. The evening shift is renowned to be more collaborative across boundaries and less weighted down with politically segregated histories.

The gap between the two CoPs stems from a distinct division of labor based on job descriptions rather than skills and organizational membership (Lawler & Ledford, 1992). This is reified in that the assembly instructions are constructed as detailed job descriptions that are supposed to convey to the assembly operators what work they are supposed to conduct for their wages. The CoP of assembly operators often regards the SPRINT printout as a means of control from the office. Of course this notion is reinforced when their feedback regarding the instructions is not considered important.

5.2.3 Accuracy

The generation of assembly instructions was one of the last things that were considered when developing the SPRINT system, or as the SPRINT database administrator puts it:

"They had spent a lot of time and money to get everyone in the global organization to agree on the data model and functionality, and then it struck them – we have to have assembly instructions to be able to assemble the trucks!"

(SPRINT database Administrator)

The standard SPRINT printouts do not fully support all assembly tasks, this means information must be collected elsewhere. At many of the more complex stations, e.g., EXOP the MUL are supplemented by additional instructions based on pictures that are placed in folders at the station. While many operators expressed the necessity of these additional instructions, they also expressed frustration over having to search for information at other places than in the MUL. There was also a problem with the folders not being up to date and pages missing.

"Sometimes the folder is not where it is supposed to be and when you finally find it, the instructions for the type of chassis you have in front of you are not in the folder".

(EXOP-operator)

The problem with the instructions not being up to date is that the operators must seek their information elsewhere and in time this renders the instruction obsolete from the operator's point of view. It simply becomes easier to assemble from prior knowledge or ask a colleague. They perceive the chances of getting the correct information higher with this course of action then if they where to consult the instructions. Of course this increases the risk of missing potentially important updates.

Many of the EXOP-operators could easily see the potential in a paperless system since they often need to seek additional information they were very positive to the thought of the possibility of having access to all information in one place.

"If I where to mount a part that I am not familiar with and I could just click on the part number and a picture of that part would pop up… that would be great".

The citation does not only point to the wish for simplicity when seeking additional information but also to overcome the uncertainty of the system with printouts in a folder.

5.2.4 Amount of information

The amount of information the operators need to assemble correctly is highly individual. Some operators claim they only need to know which type of chassis it is and look at one or two part numbers to assemble correctly.

"Like at this station I see it is a FH and then I know which fan hub it is supposed to be then I see 595 and 591 then I know exactly".

(Operator)

Unfortunately, there is much information in today's instruction that has nothing to do with the actual assembly. It describes in more general terms what is expected to be performed during the assembly cycle. Things like read the instruction, throw away empty packing-paper and order pull-material are listed in the instructions. The problem with this kind of information is that it communicates that not all information in the instruction is important.

"I never read that stuff! I don't even know why it is there. I mean we all know we are supposed to do those things".

(Operator)

All the redundant information also makes it harder to get an overview of the instruction.

"Some people do not look at the MUL at all. You tend to look for the things that deviate".

(Operator)

The overview is important because many operators only look for the things that deviate from what is perceived as normal. At the workshops conducted at SAAB Trollhättan and VCC Torslanda we were shown examples of how their assembly instructions are formatted and it appeared that the information is very sparse. They fit all information for the entire line on one A3 paper. This is due to that each operator performs fewer operations at each station and that they have more of a finite amount of variation to each model than the Tuve plant has. Nevertheless, the assembly operators at the Tuve plant look rather little at the instructions concerning the amount of information it contains.

The deviations and errors reporting processes are not only dispersed, but the cumbersome handling of these creates inertia when it the operator is faced with an issue. Papers are distributed by hand and some information by word-of-mouth which creates a Chinese whispering game. Several systems have to be consulted to accomplish some tasks. The redundancy and dispersed processes impair accuracy and quality of communication and information.

Today's system has no support for adjusting the instruction to the individual and this creates redundancy and a certain degree of information fragmentation within the instruction. That not all assemblies are supported by the SPRINT printouts also adds to the fragmentation. The divergence of the boundary object and practices is apparent.

5.3 Action planning

The action planning phase is where we specify the actions to be taken to address the problem area. Drawing on the core problem dimensions from the diagnosis phase, fragmentation and opacity, we developed design principles that would guide us through the action planning step of the action research cycle. Our research objective was to find generically applicable design principles that enable convergence of practices by means of well-advisedly designed boundary objects. The core problem dimensions being *fragmentation* and *opacity,* we decided that our principles must address these. Considering this we decided to conceptualize our design principles as:

1. **The principle of defragmentation,** to avoid dispersion of processes and artifacts.

2. **The principle of transparency**, to give everyone access to all information, is one implantation of the transparency conception. The transparency of a tool means that it is "supportive and invisible".

Our subsequent involvement in the planning of actions then utilized these.

During this phase of the study we participated in a workshop at Volvo Powertrain in Skövde where we discussed and explored the technical possibilities of the MONT-system together with a systems developer from VIT Skövde and our project leader. During this visit we also took time to observe the MONT-system in use at the assembly line at Volvo Powertrain where the system is fully implemented. Again we were baffled by the low utilization of the instructions at hand. Assembly operators occasionally glanced at the screens, but the lion's share of the instructions was not used at all.

The VIT main incentives for the prototype, cost reduction and assembly assurance together with our design principles set the framework for which ideas were to be considered for implementation in the prototype. The systems at VTC's Tuve plant, in particular the MONT system set the technical environment for the prototype work. During the action planning phase we interviewed production quality personnel to inform us whether the quality of the assembly instructions was a concern for their department. This was not the case, but QULIS administrator Ingmar Ohlin stated that quality issues that stems from errors in the assembly instructions are in a clear majority amongst the errors they handle and generate large expenses for the VTC Tuve plant (personal communication, 27th of March 2007). This was yet another incentive for the client organization to look into the processes for feedback regarding the instructions.

The prototype team, with the practitioners from VIT and VTC and us Master Thesis students, continued the collaborative action planning work and we considered in which ways we could meet the Volvo incentives and our design principles. The practitioners' focus inclined towards GUI design, information structure and hardware considerations, while ours inclined towards to constructing remedies for the problems discovered during diagnosing through implementation of the design principles. One clear division between the practitioners' expectations on the prototype ours were in that the practitioners viewed the prototype as a means for evaluating more efficient assembly instructions display. Whereas we saw this as a clear effect of enabling boundary spanning through making the prototype a concern for both the CoP of production engineers and the CoP of assembly operators. However, on the assembly operator "level" our principles came to good use. The principle of defragmentation can be applied to the presentation of assembly instructions, implemented as a reduction of redundancy and intuitive ways to find additional information. The principle of transparency can be guiding in the "physical" design of the information environment like hardware considerations (PDA, tablet PC, Stationary PC, etc.,) and sequencing of tasks to fit the assembly order preferred by one specific operator. During the action planning phase, we referred to Faulkner's (1998) design principles for GUI design for discussing transparency at the GUI level. More theoretical foundations were fetched from Detlor's framework for corporate portals design (2000) and Lucy Suchman's work on cognition and context (1987).

The boundary spanning focus draws theoretical support from Levina & Vaast (2005) and Pawlowski et al. (2004). We considered ways of implementing the principles in the form of gathering the overabundance of boundary objects and information processes into one interface (the principle of defragmentation), both for the production engineers and the assembly operators. The principle of transparency could be utilized through opening up the processes regarding deviations handling and keeping all information treatment at one point at the assembly station to avoid inertia due to physical distance from the PC terminal or similar. The improved boundary spanning, through a well-researched assembly instructions' boundary object, was supposed to present a solution to the problems we identified during diagnosing.

5.4 Action Taking

Together with the other members of the prototype team we explored the possibilities of implementing our design principles. For technological simplicity, station 5 at the motor line were chosen for prototype implementation. Station 5 is quite simple with a low degree of variation and the station with the fewest parts to assemble at the motor line. The more complicated EXOP station would have been a more interesting domain for implementation, but the complexity of assemblies performed there requires a more extensive preparation of parts and instructions. Our prototype ran in parallel with the regular production system and the preparation for the prototype station was made separate. The cost of the effort of the double preparation of parts and assembly instructions at the EXOP station was too high for the project.

Besides evaluating the possibilities for design principle implementation, we also suggested changes to the user interface that did not have an immediate connection to the boundary spanning qualities of the system, but to the design of supportive functions to the assembly operators. The feedback reporting interface was integrated to the instructions presenting interface (the modification of the MONT system) and below is a screenshot (c.f. figure 5).

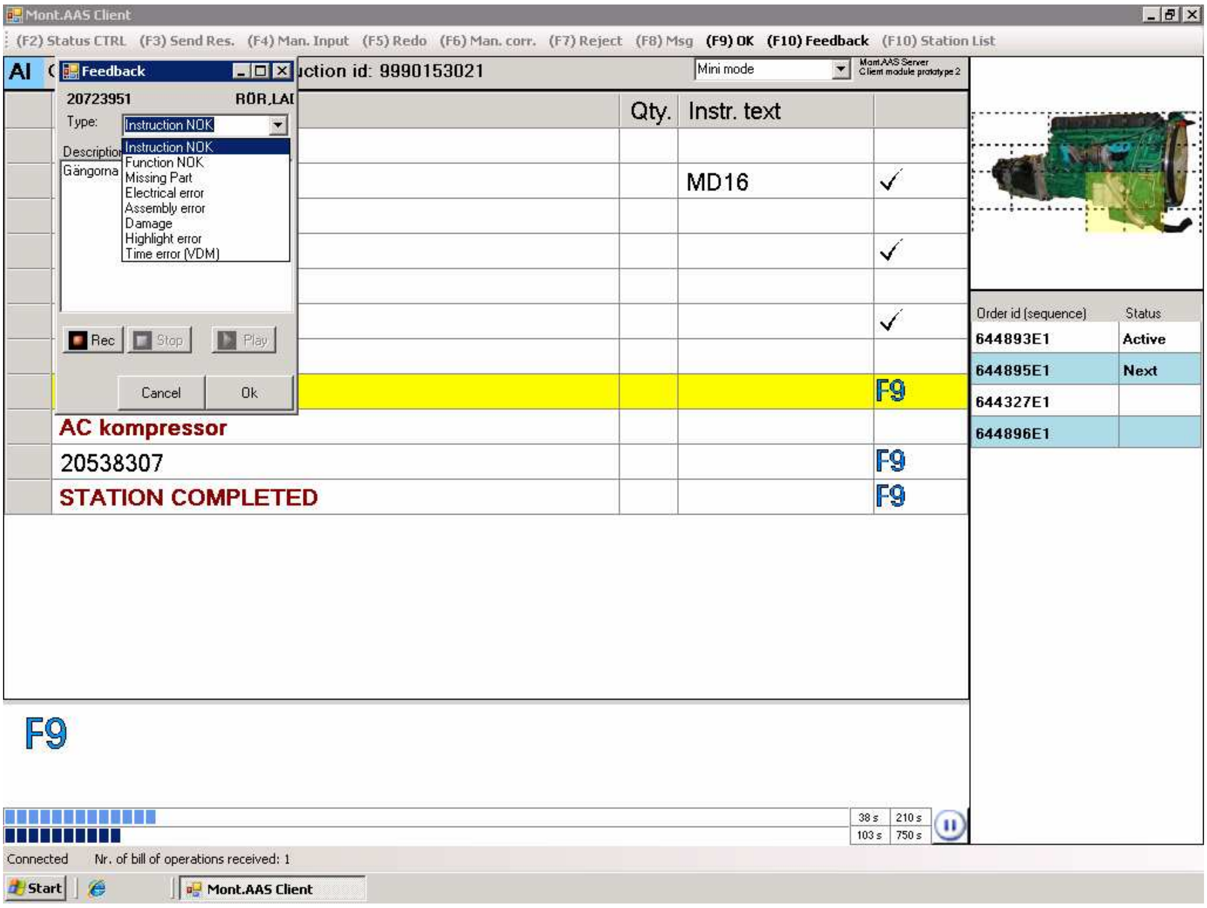

Figure 5: The feedback/deviations reporting interface integrated with the assembly instructions interface in the mini mode.

The integrated window labeled “feedback” has a dropdown menu of categories to choose from for standardized categorization of the report and each time the operator engages the reporting module it receives current chassis ID and instruction ID to make it easier for both production engineer and operator to trace the issue once it has been started. The categories were *Instruction NOK (Not OK), Function NOK, Missing Part, Electrical Error, Assembly Error, Damage, Highlight Error* and *Time Error*. The needs for the latter two were discovered during evaluating of the prototype and introduced accordingly. Below the menu there is a text field for a complementary description of the deviation and if this seems cumbersome the operator can engage the voice recording function operated by the buttons labeled “rec”, “stop” and “play” at the bottom of the window. To register the report the operator presses “OK” or “cancel” to dismiss it. This is a description of the final version of the interface. It was reworked continuously during the evaluating phase.

After the report has been registered, the control zone operator, GO or the quality support person inspects it and creates an issue in QULIS. The QULIS issue handling system, as described in Appendix 1, should be used to create structure in the deviations handling and all personnel should have access to the system for tracking and commenting on descriptions and actions.

After the issue in QULIS has been started there will be a significant increase in precision of the information reported compared with the as-is case. The Chassis ID, instruction ID, assembly operator ID, the standardized category of feedback together with a time and point of discovery data that will be attached to the initial report (we sometimes referred to this as a flag or marker during the evaluating to separate it from a full-scale QULIS issue). This makes it easier for quality personnel and production engineers to trace deviations and get an overview of problem areas. The interface is thus intended to be a transparent and defragmented tool for the assembly operators. The data that is recorded is intended for increasing the transparency and defragmentation dimensions for production engineers and quality personnel. Thus both design principles 1 and 2 have been utilized to a large extent for the design of the feedback process.

There is still one piece missing in this chain of information treatment though, the “hub” or forum where the deviations issues are collected today and the MONT systems are not connected today. This is an important connection, but due to the limited time for our project we were not able to implement the systems coupling. When evaluating this part of the concept we were instead reduced to use screenshots from the QULIS issue handling module (c.f. appendix 1) to illustrate this part of the concept.

Guided by the principle of defragmentation, we addressed the problem of dispersion of the key instructions within a specification for an assembly station by implementing three different modes in the prototype. We labeled the modes Mini-, Normal-, and visual mode. We agreed that that not all information that is present in the instructions today is necessary for all assembly personnel so we added the possibility of choosing the information richness in the instruction by adding these modes. Mini mode only showed the main part number and corresponding instructional text, all brackets and bolts where omitted. The Normal mode was like Mini mode only it also displayed short film clips of the more complicated assemblies (c.f. fig 6) and this in turn would then show the part numbers of brackets and bolts. The Visual mode would display all the part numbers and also show film clips (c.f. fig 7)

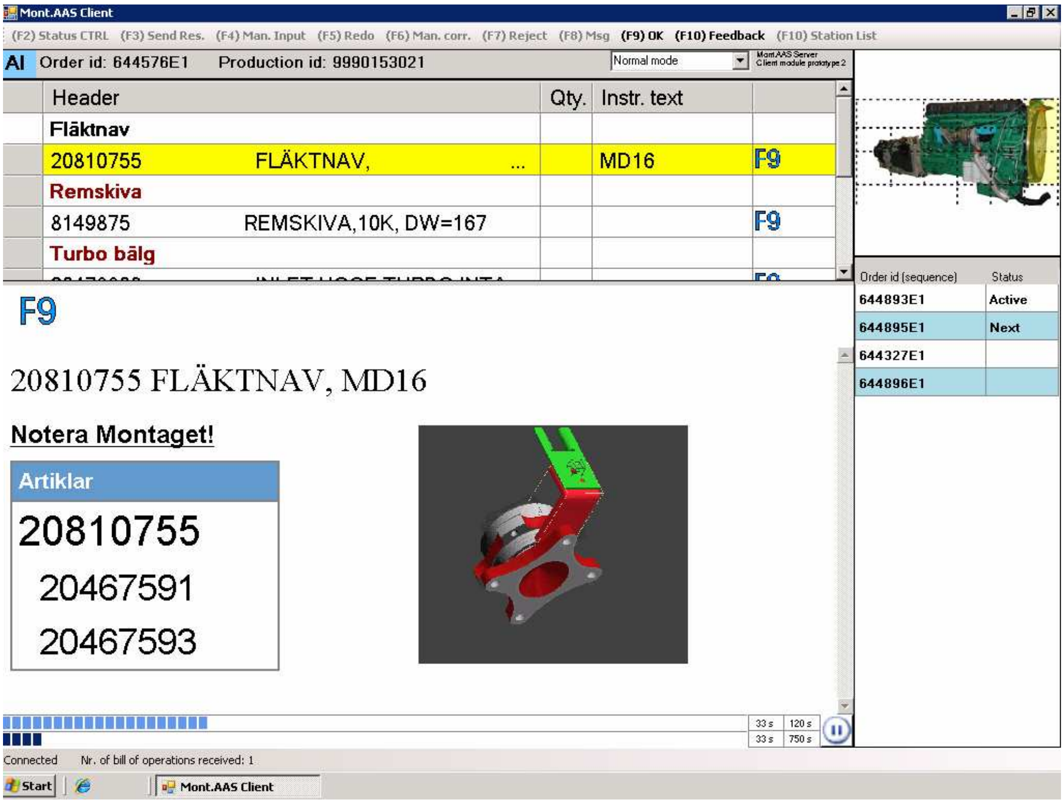

Figure 6: *Displaying normal mode in assembly instruction interface*

We argued that if the assembly operator knew that only information that is vital was displayed, this would increase the will to read the full instruction; furthermore, it would also make it easier to get an overview of the instruction and thereby easier to assess whether anything is deviating from the ordinary.

Following our design principles, we addressed the problem with other instances of fragmentation discovered in the diagnosing phase by implementing the possibility of showing film clips and 3D-images of complicated assemblies and rare parts. This function would eliminate the need for the folders with additional instructions at the EXOP-station. The production engineer can force a film clip to be shown during a certain amount of time to emphasize a certain assembly which would eliminate the need for temporary instructions being posted on notice boards. The implementation of the feedback module together with QULIS is aimed at reducing the manifold channels for handling deviations and give a single, structured, shared and transparent platform for handling deviation. The feedback module connected to QULIS would significantly reduce the fragmentation. By giving the operators the possibility of following the issues created in QULIS they would not only get a confirmation that their efforts in reporting are not in vain. They would also be able to give and receive continuous feedback from the production engineers and thereby provide the means for negotiation of the instructions. The feedback exchange would also provide the means for an increment of the understanding of each other's practice which would help to bridge the gap between the communities.

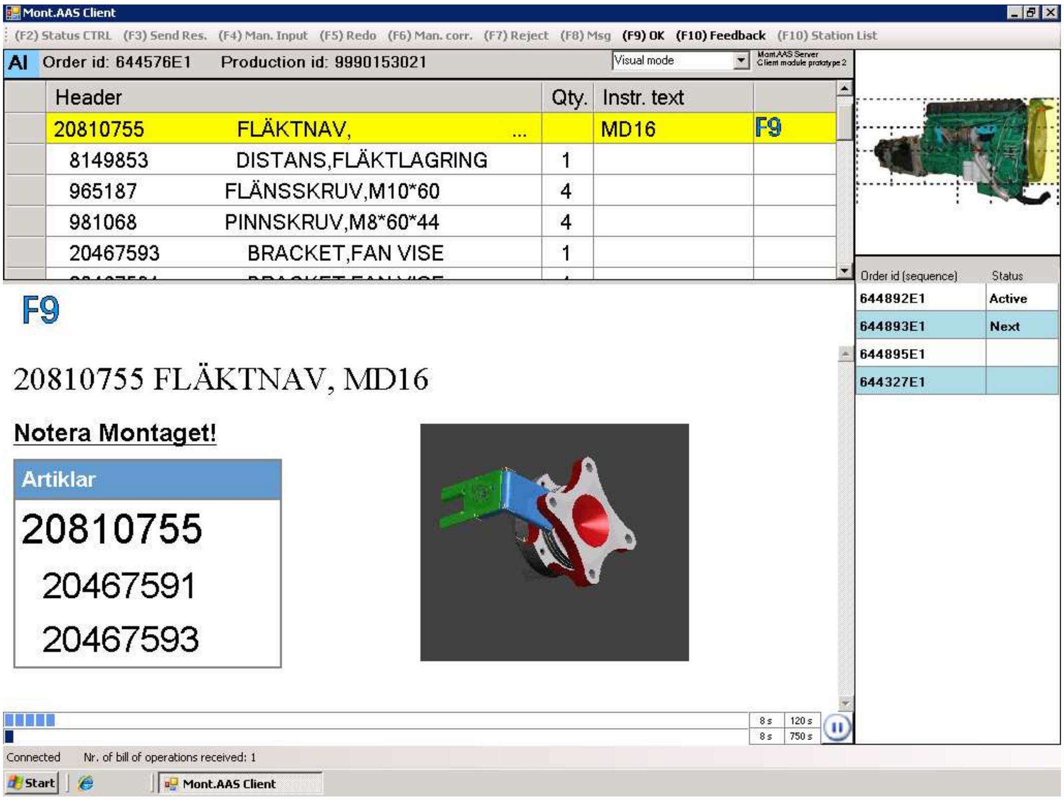

Figure 7: Displaying Visual mode in assembly instruction

To make sure that as many members of the community of assembly operators as possibly would agree as to the purpose of the prototype and what outcomes could be expected from it, we planned to have an information meeting with all the operators at the motor assembly line. As stated by Folger & Skarlicki (1999), *"Organizational change can generate skepticism and resistance in employees, making it sometimes difficult or impossible to implement organizational improvements"*

Knowing that people are not always positive to change we found it would be useful to communicate that this was not just another system that would be implemented without them having any say in it. The prototype is just a tool for evaluating the feasibility of the design concepts. We hoped that this information meeting would increase the will to use the prototype and thereby simplify the collection of empirical data. Some of the assembly operators had already been in touch with the prototype team during the diagnosing. However, we expected that there would be a great number of assembly operators that did not know anything of the prototype beforehand.

5.5 Evaluating

The prototype run lasted for three consecutive weeks. During this period we visited the plant several times to evaluate the implementation. We conducted brief interviews and collected bits of feedback that guided our continuous redesign of the system. The redesigns consisted of addition of categories to the deviations reporting interface and an addition of a function for voice recording for adding comments to the report. Furthermore we examined the architecture of the posterior processes that need to take care of the input from operators. Towards the end of the prototype run we conducted in-depth interviews with four assembly operators from the day shift and two from the evening shift. The respondents were chosen with regard to years at the motor line, previous background, gender, ethnicity and assignments at the assembly line. We ended the evaluation cycle with one last collaborative workshop where the interviewees attended together with two production engineers from different segments of the assembly line.

Just before implementation of the prototype, we participated in a biweekly information meeting with the assembly operators to inform about the purpose and function of the prototype. There was some skepticism regarding the political motives for the prototype like

" are we supposed to verify every single assembly from now on?"

"aha…it is supposed to make us more efficient so that Leif [Johansson, Volvo Group CEO] can make more money…"

"Is it for controlling the balance times [the time assigned for each assembly event] *so we will get more work at the stations?"*

(Assembly operators at Information meeting 12th of April 2007)

The skeptics became a bit less persistent when we explained that our interests in the prototype were purely academical and that our objective was to improve the processes regarding the assembly instructions. When we explained that we were going to try out a concept for reporting deviations and give feedback to make the instructions more accurate and suitable to their work we got a mixed reception. Some of the attendees were skeptical

"ok, that seems like a good idea but will we get the full scale system then? It's a question of money I guess…"

(Assembly operator at Information meeting 12th of April 2007)

Others expressed guarded enthusiasm. We did not get the opportunity to display screenshots at the meeting and could only explain the functionality briefly, but we got to draw the operators' attentions to the technical details during the prototype run.

The evaluation period had not gone on long before operators complained that we had omitted too much information when we designed the Mini mode. We realized that this was something that had been overlooked and we saw that it was necessary to investigate which parts were essential to show. We soon came to the conclusion that the parts that varied the most were required to be shown no matter what mode were made active. The operators were asked who should decide exactly which parts that should be mandatory to show. They of course answered that the assembly operators should be responsible for that. When asked how this should be done they answered that this was something that the feedback module could facilitate. Since we had no possibility of correcting the problem with Mini-mode within the given period, the operators where asked to always use Normal or Visual mode. This produced a consequence we had not anticipated. When the operators switched to Visual/normal mode they could no longer see the entire instruction at once on the screen. The operators had to press the F9 button to verify that they had finished a task to make MONT scroll down and show the next task. This brought the operators' attention to the assembly order and they pointed out that often they do not follow the order in the SPRINT printout. The visual mode made it nearly impossible to utilize a different assembly order.

"That's a bit too complicated. If you have to press F9 after every task I have completed if you know what I mean. That it scrolls down to each… we all mount in our own way… some follow the MUL and some don't. I can't say that I follow the order in the MUL. I mount as little bit here and a little bit there... the way I find it best. You want to have the freedom of choice and then I wont use it if it follows the order of the MUL

(Operator)

To be able to fully remedy this problem the system would have to be built so that it would be fully customizable to the individual. This would demand some kind of database of personal preferences or a categorization of assembly operators into a finite set based on the set of demands from each. The latter approach could be applied in a fashion similar to the three modes/level of detail for the instructions display. During an interview with the SPRINT superuser we learnt that today the sequence of the instruction is set locally by the production engineers. He pointed out this will not be the case in the future. The goal is to be able to set the order once and distribute it to all factories worldwide.

"… The question is who is responsible for setting the sequence, today it is set locally by the production engineers. Tomorrow this will not be the case; it will then be set globally… There are pros and cons with this, in some aspects it does not matter but others are important. If you look at… I think it is VCC they just receive a package with preset instructions for which the time usage is calculated and then it is up to the factory to find the best way to structure these instructions. The factory that finds the most efficient way to mount gets a bonus and their sequence is then communicated to the other factories".

(Sprint Superuser)

This new way of handling the assembly sequence further strengthens the need for negotiation of the content in the boundary object. The feedback module together with QULIS provides the necessary tools for negotiation of the reification of the practice.

The operators do not want a fixed assembly sequence or any control of their performance at all

"Well, what I would want is that when I arrive at an assembly station the following were to be appear [pling] –Don't forget that there is a change to the LLK-tube, or now we have changed this or that. Be observant on this and good luck with your assembly! Press F9 when finished"

(operator)

To apply a fixed assembly sequence might choke the inventiveness of the assembly operators. The assembly sequence that would be determined by the global technical department in the future has to be tried out in a real context. Enabling the continuous improvement of the assembly sequence in a "best practice" manner would require a continuous validation against real assembly operations contexts. The feedback system could facilitate this. The transparency of the shared information system is critical for the assembly operators' motivation to engage in the boundary spanning practices. It is also critical for the global technical department for gaining insight into the assembly operators' opinions on the efficiency of the instructions' sequence.

The opportunity to reduce the amount of information by choosing the mini mode (c.f. figure 5) was intended for reducing the dispersion of information by applying design principle 1. The information presented at station 5 in this mode were stripped down to what we thought would be a minimum. We tried out different setups of minimal information provision and it became clear that the operators could perform their task from three key items.

"Mostly we get the 13-litre and it's pretty obvious for most [of the assembly operators] what should be assembled. But certain stuff you look for… e.g. bracket fan vise. Those two you look for."

(operator)

In conclusion, the implementation of our design principles in the prototype had a distinct impact on how the assembly operators viewed the potentials for a full-scale rollout of the system. The possibility of getting transparent access to information regarding errors and deviations clearly appealed to the assembly operators.

"That is great! Because as it is now it feels as if… if you ask the production engineers about something you never get an answer back. You do not notice any difference, or you don't feel any difference. It is as if we report and report and they just sit there and receive it. We want an answer back! We want a confirmation that it is received and an answer back"

(Assembly operator's opinion on the prototype concept)

The quotation above is typical of the responses we received during the interviews. Our solution to the problem of lacking attention to the instructions' error handling process, integrating a simple reporting interface into the instructions interface and use the input from this to start issues in the production quality system, got a very positive reception amongst the community of assembly operators. The community of production engineers came to anticipate a more structured process for reporting deviations. This would facilitate more precise reports and less confusion.

"This would give the production engineers a better understanding of the every day problems that we face. It is definitely raising it to another level… it feels as if we would be seen… as if our problems are important".

(Assembly operator on the connection to QULIS)

The operators felt that this would be a help in overcoming the problem with the endless reporting without effect. They also believed it would create a better understanding of their practice in the community of production engineers.

The production engineers admit that they do not pay close attention to all reports regarding errors with small impact on quality.

"Often when you receive a report it is so diffuse that you cannot do anything without further investigation. If it is'nt a critical error, you don't have the time to trace what it is all about"

(production engineer)

To get more precise reports and shorten the path between reporting operator and production engineer would increase the production engineers' devotion to correct the errors.

"…you mean we would get instructions and chassis ID in the report? That would help a lot… sometimes its to much work to find out what the length of a bolt or a tube should be to make it fit. You trust that the operators fix it… it would be better with fewer middle men"

(production engineer at final workshop)

5.6 Specifying Learning

Here we display an analysis of the results from the previous phases and what knowledge has been gained.

The diagnosing phase of this cycle of CAR revealed many interesting problems in the research context. The most acute problem was the rigidity of the boundary between the community of assembly operators and the community of production engineers. We identified several factors that contributed to this rigidity.

- The instructions were often inaccurate and outdated. Updates and temporary changes were often communicated on notice boards along the assembly line. The inaccuracy of the instructions and the dispersion of the instructions caused irritation towards the production engineers amongst the assembly operators. The instructions also contained redundant information which made them cumbersome and difficult to overview

- The processes for reporting errors in the instructions were nor transparent and the assembly operator had no way to know who handled the error report and what action was taken by the production engineer. The time from reporting to implementation of corresponding changes could be as long as 6 months or longer. This caused irritation and the motivation to report errors and deviations were very low amongst the assembly operators.

- The production engineers on the other hand did not get many instructions' error reports, thought that there were not many errors causing problems, and that the assembly operators could manage minor problems. The error reports they received were often not precise enough for the engineer to choose a corresponding action.

The main boundary object, the assembly instructions, had not been thoroughly negotiated and this made it an inefficient means for communicating expected tasks. As a consequence, the assembly operators performed their assemblies based on prior knowledge, some key pieces of information gathered from the instructions and by recognition of the type of motor.

The accuracy of the instructions and how effective it conveys information to the assembly operators was not regarded as quality factors at the Tuve plant. The QULIS administrator states that a very large and expensive part of the quality issues that are registered in the system stems from errors or misinterpretations of the assembly instructions. There is a discrepancy between this awareness and that very little work has been done to create processes to work with quality of the assembly instructions. For VIT and VTC, one important outcome of this project is an understanding for the importance of the quality of the instructions.

The dispersion, or fragmentation of information sources and processes was another cause of inefficiency in the assembly information environment. The EXOP station had several sources where additional instructions were collected. The paper based information processes at the assembly line: deviations reporting card, internal error correction form, SPRINT printouts, quality instructions and chassis ID cards were a source for fragmentation of the information environment. The physical properties of paper made this cumbersome and insecure. Documents were often lost when transporting a chassis between segments.

The core problem dimensions from diagnosing, opacity and fragmentation, lay the foundations for the design principles of transparency and defragmentation. During action planning we surveyed alternatives for implementing these in the prototype and adjoining systems.

In action taking phase we decided to integrate a small feedback/deviations reporting interface in the graphical user interface (GUI) of the prototype and link this to QULIS. The integrated interface had a predefined set of categories for clarity. Options for free text and voice recording were included and the intention was that together this would provide information about the chassis ID, instruction ID, assembly operator ID, assembly station ID, feedback/deviation category and input from the assembly operator so that the control zone operator could simply start an issue in QULIS by confirming with “OK” button or similar. This would integrate solutions to problems with several paper based information processes into the instructions interface making it a transparent and defragmented tool for the assembly operators and control zone operators. Furthermore the precision in reports would make the work of the production engineers easier. This feature would increase the transparency and defragmentation of their information environment. After an issue in QULIS had been started, the issues handling system should be accessible for all personnel at the plant. This way, the processes regarding production quality and instructions' quality would become transparent and it would be easy to extract key performance indicator (KPI) figures for evaluation.

The Volvo Group’s incentives for the prototype were realized through using the principle of transparency and the principle of defragmentation when designing the GUI. This resulted in the following modifications of the MONT GUI besides the integrated feedback/deviations reporting GUI.

- Three hierarchical levels of detail in the assembly instructions presentation GUI: Mini, Normal, Visual
- Progress bars showing the time expired for the present assembly and the station in total
- Option to show 3D animations, movies and pictures to highlight new assemblies or other visualization purposes.
- Position image guide. A miniature picture of the item on which the assemblies should be performed. The area where the assembly should take place was highlighted with a contrasting color.
- Sequence list. A list of the chassis before and behind in the assembly sequence for the day. In a full implementation these should be clickable to get instructions for these.

The different levels of details display received positive feedback although some assembly operators asked for the option of individual adjustment richness of detail rather than the general categories. Progress bars were experienced as a stressful item by some respondents while others thought of it as a good tool to measure that the station times were right. The visuals, 3D animations, movies and pictures would be supportive at the EXOP variant station where rare and difficult assemblies were performed. At other stations it was thought of as an annoyance. The position image guide would be supportive to beginners and at EXOP. If the image were zoomable and clickable it could provide some support at standard assembly stations as well. This was not tested due to the limited time for the prototype. The sequence list was a necessary item when eliminating the paper instructions. It must be possible for the operators to look at instructions for other chassis than the present at the station, e.g., when an error occurs, they must be able to look up the instructions for a specific chassis. During the evaluating phase, the prototype was first implemented on three platforms: stationary PC, tablet PC and PDA. The two latter, hand-held options were soon discarded due to that it was difficult to manage the units while assembling. At variant stations where the parts are not in close vicinity, e.g., EXOP, hand-held screens are necessary when leaving the station to gather parts. The risk of dropping the units to the concrete floor was imminent. Some functionality was modified and added during the evaluating. Voice recording functionality was added to the feedback/deviations reporting GUI to simplify reporting. The sequence list was modified to show chassis both behind and before in the sequence. The parts and assembly operations were given contrasting colors to increase readability of the assembly instructions. The feedback from the evaluating phase gave responses to the feedback/deviations reporting concept and the design suggestions for the GUI. The concept received many positive comments from assembly operators and it seemed to bring forth a possible solution to the problem with resigned attitudes towards the instructions' correction process. The increased precision in reports was considered as a great improvement from the production engineers, but natural skepticism regarding the conceivable initial leaping increment of reports. The structure and transparency that would be possible if utilizing the functionality in QULIS were appreciated by both communities of practice. The functionality of this prototype concept was appreciated by both communities of practice for whom it was intended. The positive attitudes towards the transparent handling of feedback and deviations' issues in QULIS’s issue handling system pointed to that this solution would achieve a significant overlap in the information environments and activities of the two communities of practice. Hence, this would enable the type of tightly interwoven collaboration we had labeled convergence of practices.

One unexpected organizational deliverable from this first cycle of CAR was the unanticipated difficulties regarding the sequence of assembly instructions. As long as the SPRINT printouts are used it is easy to skip back and forth in the instructions. The fast navigation property of paper can not be easily emulated with a computer keyboard when converting from part-lists extending over 3 A4 sheets to a display on a computer screen. When using the mini mode, all parts can be viewed simultaneously on one screen. Using the other modes you have to navigate, either by verifying operation by operation or waiting for the expiration of the designated operation time. When verifying operation by operation, the sequence of the assemblies becomes an issue. The assembly sequence has to be negotiated to achieve acceptance from the assembly operators. The want for freedom of choice of assembly sequence, and the way some operators structure their work by doing several assemblies simultaneously makes this a difficult issue that could have a large influence on the success of the system. Individualization could be a solution, but the company wants to streamline processes and utilize the best-practice concept. This ambiguity could however be overcome by implementing the feedback system of the prototype to its full extent. Feedback regarding the assembly sequence could be reported and this would generate a pool of best-practices that could be evaluated and updated by the global preparation production engineers. To further enable the convergence of practices, teams consisting of members from each community could be put together to choose the best practice to be used. This would add a participative dimension to the spanning of the boundary.

Brokering practices could increase the potential for convergence further. To hire and train production engineers that have started at the assembly line to an even lager extent could be one way of bridging the cultural and political gap and hence facilitate increased convergence. Furthermore, starting committees with members from each CoP that discusses the design and content of the instructions and the feedback process would enable increased boundary spanning and convergence of practices. This, however, lies far beyond the limit of our action research study, even if we would have continued with yet another cycle. The idea is nevertheless interesting for long-term organization development at Volvo Trucks' Tuve plant.

6 Conclusions

The research purpose of the study was to find ways to enable convergence between practices by means of design of shared information systems. The results from the action research study show that utilizing the principle of defragmentation and the principle of transparency will enable improved cross-boundary collaboration. The convergence of each community of practice and the boundary object established through utilizing these principles could at length enable the convergence of practices.

The answer to our research question is then that the study strongly indicates that transparency and defragmentation of information environments is critical for convergence of practices.

The conclusion from the client organization perspective is that we found that the boundaries between the community of assembly operators and the community of production engineers were very rigid. This was a result of lacking negotiation of the assembly instructions as a boundary object resulting in opacity and fragmentation in the information environments of both communities. Our design principles were developed to remedy this, the principle of transparency and the principle of defragmentation. These were implemented in the prototype and the consequences were that members of both communities got a new focus on the common processes of deviations handling. After making the processes less fragmented and opaque the potential for convergence increased notably. Brokering practices should be employed to complete the convergence of the practices through continuous negotiation of the common system and processes. The transparency and defragmentation of the shared information system are critical for the assembly operators' motivation to engage in the boundary spanning practices. It will also be critical for the future global technical department for gaining insight into the assembly operators' opinions on the efficiency of the instructions' sequences.

One of the outcomes of this project was the focus on the quality of the instructions as a product quality influencing factor. This new approach at the Volvo Group potentially increases the awareness for the need for negotiation of the instructions. The feedback/deviations reporting concept and brokering practices in the form of committees and delegations could enable and enhance the negotiation process.

The design principles that we developed and evaluated during this project are not independent. One imply the other

Transparency ⇔ Defragmentation

To achieve transparency, a shared information environment has to be defragmented, otherwise the completeness and overview will be inferior. To achieve the successful defragmentation of an information environment extensive negotiation has to take place, i.e., the process should be transparent. Otherwise parts that seem unimportant to one community of practice but are important to another may be given badly advised priorities. This became obvious when we discovered the importance of the assembly sequence.

7 Discussion

The spanning of multiple boundaries through boundary objects alone is no ideal solution. Wenger (1998, p 110) states that

“Participation and reification can each create connections across boundaries, but they provide distinct channels of connection.”

The participative activity of boundary spanning, brokering, should be utilized to enable the full convergence of practices. This project has focused solely on the reificative boundary object concept. If we had had more time at our disposal we would have dug into the potential for brokering practices in the research setting as well.

The short time span did not allow us to implement the concept fully into the prototype which made the evaluation of the convergence a bit hypothetical. However, we were able to discuss the effects of a full implementation with members of the CoP of production engineers and demonstrate the concept with aid of the screenshots from QULIS, but they could not get the “hands-on” experience that the assembly operators got from the prototype. We managed to capture some crucial points that would be expected to change their practice and converge towards the boundary object. Some effects on the organization could not be assessed without implementing the entire concept. This was without our delimited domain of research and hence a possible area for another cycle of action research.

Regarding this as our first serious research project we learned many lessons. During transcription of the recorded interviews we noticed that we sometimes interrupted chains of reasoning that was emerging from the respondents. This had a minor diminishing effect on our results. What we learned about interviewing techniques and the intuition we gained from this project will be of great value in future projects.

We evaluated our research towards the principles and the criteria suggested by Davison et al. (2004). This evaluation is accounted for in appendix 2.

7.1 Suggestions for Further Research

The participative dimension to boundary spanning, i.e., brokering, and how it can contribute to increasing convergence between practices is a possible facilitator of convergence of practices to be explored. Furthermore it would be very interesting to implement the design principles in another research domain to test their general validity. On the client side of this project, it would be of great interest to apply the principles and concepts developed in this study in a full scale implementation of the system that were prototyped.

The convergence of practices is a concept that is not mentioned in the information systems literature before. It would be very interesting to see the concept defined and evaluated further in another paper.

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9 Appendices

9.1 The QULIS Issue Handling Interface

The QULIS system deals with production quality. It is mostly used by the quality support personnel at the assembly line and the control operators. Internal and external suppliers can be contacted and engaged in the problem treatment through the system, and the issues are treated in a strict sequence. An example of how the issues are handled is depicted below. If there are construction related problems the issue generates a log in the PROTUS F system that the construction department uses for logging changes to the constructions.

ÄRENDEHANTERING - Quality Information System ID: V0P0448 Per Liljesson

Ärendenr: 1620

Startat efter: 2006403 Planerad färdigt: 2006415 Avslutad: 2006411

Rubrik: Pa-rör mot motor A:630749 Chassinr: A-630749

Beskrivning: Gul märkt 12 mm pa-rör skaver mot vass kant på motor vä-sida.

Faktainsamling	2006-10-05	
Tillfällig åtgärd	2006-10-09	
Rotorsaksanalys	2006-10-09	
Permanent åtgärd	2006-10-09	
Resultatuppföljning	2006-10-09	
Avsluta ärendet	2006-10-09	

Quils Logg

Första förekomst: 2006403

Senaste: 2006403

Frekvens: 1

Hämta

Tag bort koppling mot chassi

Kategori: Intern Åtgärd

Uppdragsgivare

Företag:

Avdnr, Namn: Persson Michael

Läst: ☐ Accepterat? Ja ○ Nej ○

Ärendeägare

Företag:

Avdnr, Namn: Simonsson Lars

Läst: ☑ Accepterat? Ja ● Nej ○ 2006-10-05 17:05

Medhjälpare

Företag:

Avdnr, Namn: Hjortsberg Martin

Läst: ☐ Accepterat? Ja ○ Nej ○

Uppföljning: 29740 Kvalitet

Protus ref:

Projektnr:

Funktionsgrupp :

Grad av allvarlighet: ☑ 25 ☐ 100 ☐ Högfrekvent

Skriv ut | Avbryt

Vägledning ärendeanalys

Faktainsamling Inom 24 timmar

Bilaga

Kontroll av chassi före.	Kontroll av chassi efter.
Inga chassin är valda.	Inga chassin är valda.

Pa-rör skaver mot motor 630749.JPG

630692,630847,630690,630565,630655 är OK

Senast uppdaterad av: 29740 Michael Persson 2006-10-05

Tillfällig åtgärd inom 24 timmar

Bilaga

Lämnat förslag till konstruktion att man montera ett clips närmast ramen som man skall sammontera kablar och rör i detta är tillsagt till del 1. Dock kan pt ej ändra i underlagen innan ok från konstruktion.
Detta innebär att om man läser underlagen gör del 1 rätt men det uppstår skav för oss. Dock brukar del 1 montera ett clips men någon har missuppfattat den tillfälliga ändringen. PROTUS FINNS 48978.

Senast uppdaterad av: 29213 Martin Hjortsberg 2006-10-09

Rotorsaksanalys inom 7 dagar

Bilaga

Montör följer instruktioner? Ja
Har montören rätt kompetens? Ja
Instruktioner är riktiga? Ja
Kontrollunderlag är riktiga? Ja

Utökad intern åtgärd? Nej
Behöver kampanj genomföras? Nej

Senast uppdaterad av: 29213 Martin Hjortsberg 2006-10-09

Permanent åtgärd

Bilaga

Tagit kontakt med del 1 och informerat om vikten att de placerar clipset rätt.

Senast uppdaterad av: 29213 Martin Hjortsberg 2006-10-09

Resultatuppföljning

Bilaga

Kollat dagens bilar v 411 och samtliga var ok.
Fortsätter med kikar under v 41.

Senast uppdaterad av: 29213 Martin Hjortsberg 2006-10-09

Avsluta ärendet

Bilaga

Protus finns 48978.
Väntar svar från konstruktion.
Tillsvidare sätter del 1 clips längst in på konsolen detta för att undvika att röret ligger och skaver.

Senast uppdaterad av: 29213 Martin Hjortsberg 2006-10-09

9.2 CAR Evaluation

To ensure our action research was carried out in a valid way we evaluated it against the framework suggested by Davison et al. (2004) that we discussed briefly in the method section. The criteria in form of questions functioned as a trigger for our discussion of the study and we provided answers/discussion in the table below.

Evaluation of our project against the criteria proposed by Davison et al		
CAR Principle	***Criteria***	***Discussion***
1. Researcher-Client Agreement	a) Agreement upon that CAR is the appropriate approach for the organizational situation?	Although we never discussed the action research method in explicit terms, both researchers and practitioners agreed upon a sequence that corresponded to a cycle in action research.
	b) Focus clearly and explicitly specified?	A clearly stated focus from both practitioners and researchers, with a substantial overlap.
	c) Explicit client commitment?	The project was initiated by the client and its commitment followed from this and remained throughout the project.
	d) Clearly specified roles of researcher and org members?	Throughout the project the roles and responsibilities of practitioners and researchers were under negotiation. At times the researchers role adjoined the role of consultant. But there was no questioning that the researchers had to conduct diagnosing and evaluating with as small intervention from practitioners as possible.
	e) Clearly specified project objectives and evaluation measures?	The objectives of the project were clearly stated, but due to the complexity and partiality of the intervention it was difficult to set out distinct evaluation measures. The results had to be interpreted.
	f) Explicitly specified data collection and evaluation methods?	Interviews and grounded theory techniques were utilized.
2. Cyclical Process Model (CPM)	a) CPM followed or justified deviation?	The CPM was followed for one cycle.
	b) Did the researcher conduct an independent diagnosing of the problem situation?	The researchers conducted independent diagnosing and evaluating.

	c) Planned actions based explicitly on diagnosing results?	Design principles for action planning and taking were developed based on results from diagnosing.
	d) Planned actions implemented and evaluated?	Planned actions implemented and evaluated.
	e) Researcher reflection of the outcome?	Researchers specifying learning through reflection contributing to both academic interests and practitioners' interests.
	f) Reflection followed by an explicit decision on proceeding with another process cycle?	There was no time for another cycle in the time span for the master thesis project so the decision were forced to be no-go.
	g) Exit of project due to objectives met or other justification	Time limit reached for researchers. Budgeted "man-hours" for VIT personnel used up and the project finished.
3. Theory	a) Project activities guided by theory?	Theory provided structure to diagnosing and planning. Evaluation methods were theoretically informed.
	b) Domain and problem relevant and significant to both practitioners and academia?	The domain and problem sprung out of a desire for change in the organization. The researchers found a relevant research domain and problem.
	c) A theoretically based model used to derive the causes of the observed problem?	Theory (primarily Wenger (1998), Levina & Vaast (2004), Star & Griesmer (1989), Star et al (2003)) guided the diagnosing of the problem and domain.
	d) Did the planned intervention follow from the theoretically based model?	The design principles developed during planning guided the action taking.
	e) Was the guiding theory used or other theory used to evaluate the outcomes of the intervention?	Evaluation through qualitative interviews. Theoretical conceptions used for structuring interview data.
4. Change through action	a) Motivation from both client and researcher to improve the situation?	Yes, both VIT and VTC staff motivated. Also the researchers.

	b) The problem and its hypothesized causes specified as a result from the diagnosing?	Yes, the problem and hypothetical causes were derived from diagnosing.
	c) Planned actions designed to address these causes?	The design principles were developed to address the causes directly.
	d) Client approval of actions before implementation?	The actions produced in collaboration with practitioners.
	e) Organization situation assessed comprehensively both before and after the intervention?	Yes at diagnosing and evaluating respectively.
	f) Timing and nature of actions clearly and completely documented?	There was some lack in the documentation of timing for the actions.
5. Learning Through Reflection	a) Did the researcher provide progress reports to the client and organizational members?	During the short time span, a few short oral and written reports were given from the researchers.
	b) Did both researcher and client reflect upon the outcomes of the project?	Yes, during the compilation of the internal VIT report from the prototype and at the concluding workshop researchers and clients reflected upon the outcomes.
	c) Research activities and outcomes clearly and completely reported?	Due to the fast pace there was minor gaps in the precision of the documentation. All activities have nonetheless generated records.
	d) Results considered as implications for further actions in this situation?	The prototype project was implemented in a one segment of the assembly line. It was supposed to evaluate the feasibility of the concepts for implementation throughout the entire assembly line. The response to the internal VIT report were positive, but it remains to be seen if the financial means for full scale implementation will be raised.
	e) Results considered as implications for further actions in related research domains?	We consider our design principles valid for a wide variety of applications regarding communication of instructions and design of boundary objects for convergence of practices in general.

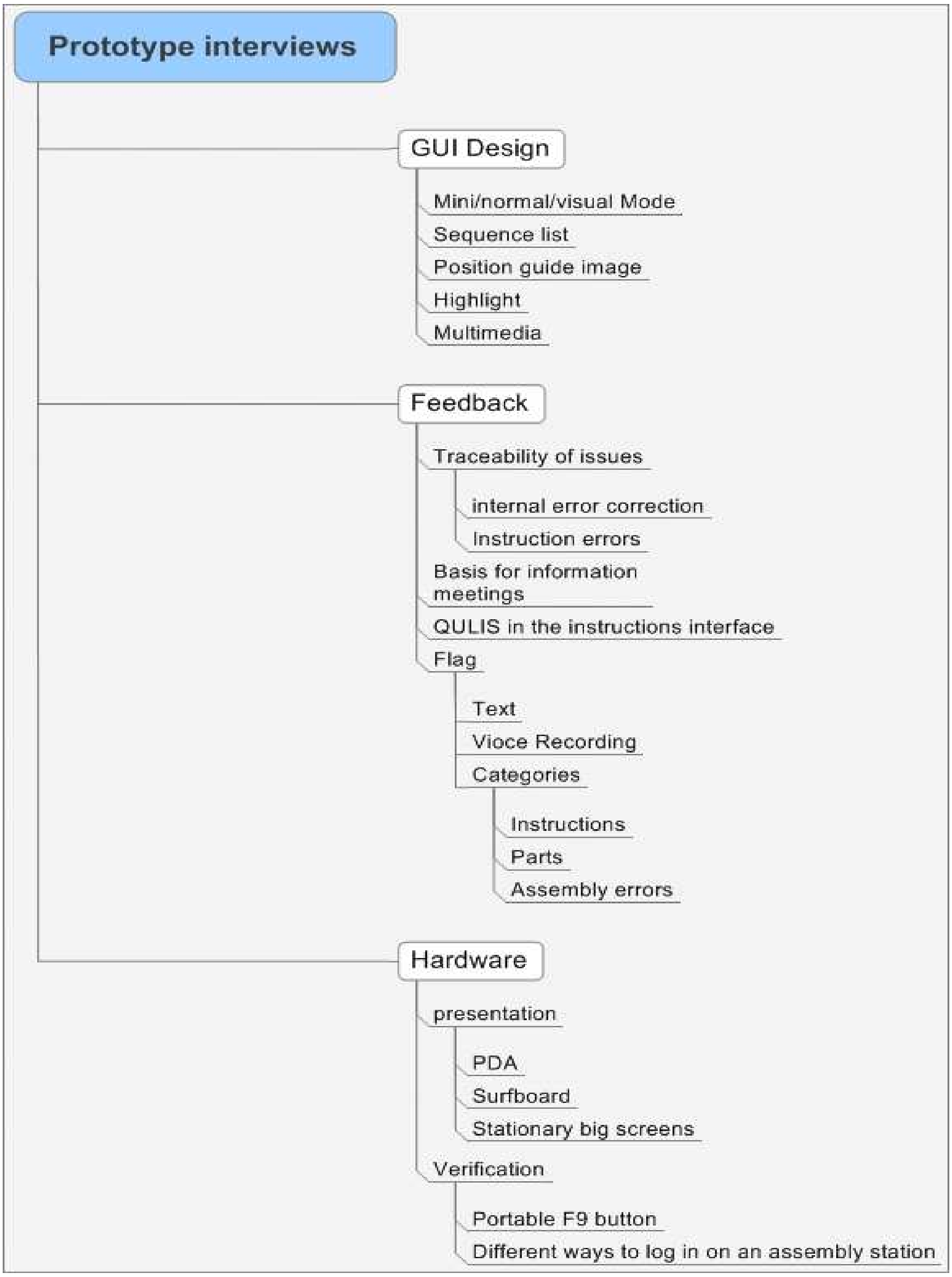
	f) Results considered as implications for research community (knowledge, theory)?	The concept of design for convergence of practices is not previously mentioned in the literature and this should be further researched.
	g) Results considered in general terms of general applicability of CAR?	Provided the Researcher-Client agreement is fixed and the domain and problem is well specified it is fully possible to complete one full cycle of CAR using the principles of Davison et al for ensuring rigor and relevance.

9.3 Respondents from evaluation interviews

Respondent	Function	Age	Years on task	Gender	Education, Other
MI	Operator, EXOP, adjustment, evening shift	22	½year	F	Volvo Senior High School
MA	Operator, Quality support, Control Operator	29	7yrs	M	Technical Senior High School
SAM	Operator, evening shift	23	½year	M	One year at Chalmers, One year at Gothenburg University: public administration program Previously from Volvo Cars
SAN	Super User SPRINT, former assembly operator and production engineer.	25	3yrs	M	Works in the office. Started out at assembly. Technical College
N	Operator, EXOP, adjustment	39	7yrs	M	Journalist education in Poland, hairdresser, Automobile mechanic for two years in Iran.
A	Group coordinator, control operator	30	6yrs	M	Economics in Senior High school
F	Operator, Control Operator, group coordinator, acting PL	33	5yrs	M	Truck driver 10yrs prior to this. Industrial, techincal/workshop Senior High School 3yrs
SG	Production engineer, Special Montages				Gothenburg Technical high School
AH	Production engineer				Started out as assembly operator

9.4 Interview Guide

Our interviews included themes from the work of the prototype team that were not in direct association with our research area, but this made for a natural line of reasoning through the interviews. We utilized a simple checklist to guide the interview work.



9.5 Deviations Handling Process Map