Engineering for Shared Understanding in Heterogeneous Work Groups - An Action Research study at a German Automotive Company

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Abstract: Heterogeneity in work groups creates challenges to build a shared understanding among diverse group members and to integrate knowledge of different actors successfully. In an action research study with experience diverse tool and dye-makers at a German car manufacturing company, we developed a collaboration process design to systematically support heterogeneous groups in building a shared understanding of the sequence of activities in complex work processes. Participants showed the intended team learning behaviors and an increase in shared understanding.

Keywords: Collaboration Engineering, Shared Understanding, Knowledge Integration, Heterogeneous Groups

Introduction

Motivation

Research on group work has shown that collaboration is critical for organizational productivity, as many tasks exceed the cognitive capabilities of any individual, due to their complexity (Fischer 2000; Langan-Fox, Anglim et al. 2004). It also shows that diverse groups can perform better on complex tasks than homogeneous groups (Bowers, Pharmer et al. 2000; Wegge, Roth et al. 2008). The existence of heterogeneous perspectives or "symmetry of ignorance" in groups has the potential to provide opportunities for creativity in solving ill-defined, wicked problems (Fischer 2000).

Heterogeneity in teams often leads to communication breakdowns and project failure. While group members usually do not have to be experts in all fields tackled by a complex project, "they have to be able to integrate their knowledge bases in a sensible manner" (Kleinsmann, Buijs et al. 2010). Otherwise, they might be unaware of unshared individual knowledge which could be crucial for completing the task successfully. Building a shared understanding "is important because people frequently use the same label for different concepts, and use different labels for the same concepts. People on a team also frequently use labels and concepts that are unfamiliar to others on the team" (de Vreede, Briggs et al. 2009). As no standard definition of shared understanding has evolved yet, we define shared understanding as an ability of multiple agents within a group to coordinate behaviors towards common goals or objectives based on mutual knowledge, beliefs and assumptions on the task, the group, the process or the tools and technologies used, which may change through the course of the group work process due to various influence factors and impacts group work processes and outcomes (Bittner and Leimeister 2013). The challenge is that diverse work groups may lack a shared understanding of the task, the characteristics of the group, the products to be developed or the collaboration process due to their different background and experience.

If techniques and processes can be applied that support the creation of shared understanding in diverse groups, those groups are expected to gain efficiency in their work and produce better results. This paper examines the challenge of knowledge integration in heterogeneous work groups in a real world setting at a German car manufacturing company. We chose and action research approach to develop a solution for the specific problem situation, while simultaneously investigating the phenomenon of shared understanding and knowledge integration in heterogeneous teams. The practical goal of this project is to design a reusable collaboration process by which experienced and inexperienced group members should increase their individual understanding by adopting knowledge from each other and agree on a shared understanding of a specific work process. The research goal is to exploratively generate new insights on the mechanisms leading to shared understanding in heterogeneous group work. While a basic version of the process logic itself was proposed earlier (Bittner and Leimeister 2013), we address the following questions here: How do the designed collaborative work practices evoke group learning mechanisms? How are these mechanisms related to changes in shared understanding in the heterogeneous groups?

The paper is organized as follows: First we point out our underlying understanding of shared understanding. In section two, the research setting and our action research approach are outlined. Sections three to seven follow the action research logic and describe, how we (3) diagnose, (4) plan, (5) intervene, (6) evaluate and (7) specify the learning in the action research study. The paper closes with a consideration of implications, limitations and outlook on future research.

Shared Understanding

Two differing interpretations of "shared" can be found in literature, the division of a resource between multiple recipients versus the joint possession of some resource (Smart, Mott et al. 2009). While the former refers to the distribution of tasks or knowledge among different actors, the latter covers the phenomenon we see in shared understanding. Groups, who are engaged in collaborative work need to have a joint reference base of knowledge and understanding in common in order to work productively. Thus, we focus the definition of "shared" for our purpose as some resource being possessed jointly by several people, based on "the overlap of understanding and concepts among group members" (Mulder and Swaak 2002). "Understanding is an ability to exploit bodies of causal knowledge (i. e. knowledge about the antecedents and consequents of particular phenomena) for the purpose of accomplishing cognitive and behavioral goals" (Smart, Mott et al. 2009). This definition of understanding highlights the importance of both knowledge as facts, and the structure of this knowledge. Causal knowledge is necessary for directed action towards the group goal. Seeing understanding as an ability, or "meaning in use" strengthens the viewpoint that understanding is more than knowledge, but involves reasoned action (Cannon-Bowers and Salas 2001; Mohammed, Ferzandi et al. 2010). "Shared understanding refers to mutual knowledge, mutual beliefs, and mutual assumptions" (Mulder and Swaak 2002) in order to reflect subjective aspects of understanding and future oriented assumptions in addition to objective factual knowledge. We make this inclusion, as especially for complex tasks, there might not be one single right understanding. The construct of shared/team mental models is closely related to shared understanding (Hsieh 2006) and is thus included in our work wherever useful, especially for the assessment of documents generated throughout the process. Although it is differentiated from shared understanding by some authors due to its stronger focus on command and control teams with highly structured tasks (Mohammed and Dumville 2001) and its lack of consideration of evaluative beliefs (Mohammed and Dumville 2001; Langan-Fox, Anglim et al. 2004). . In the study at hand, we focus mainly on shared understanding concerning the group task, in particular the work process the group should document.

Methodology

Research Setting

The authors were asked to improve collaboration of experienced and inexperienced tool and dye makers and increase the mutual knowledge transfer to ensure the retention of tacit knowledge within the organization independent of individual people. The organization was a big German car manufacturer. The goal was to build training blocks that helps inexperienced worker to execute complex work tasks.

As many other organizations, this company faces an increasing challenge to enable its members to integrate diverse knowledge. Longtime employees with great experience and deep understanding of the company's processes are confronted with unfamiliar rapid technological change in their work environment. When approaching retirement age, the organization is endangered by losing the skills and tacit knowledge of those people, if no appropriate means are in place, which support the transfer of knowledge to new employees. New employees on the other hand bring recent technological education and an unbiased view on established work processes, but may lack the specific skills and expertise in highly complex fields. Young employees with recent educational knowledge and older, more experienced employees should be able to learn from each other to prevent critical knowledge from disappearing. Demographic change enforces this challenge, as a big proportion of experts are reaching retirement age and only a small number of young technicians are qualified to fill their positions. Both experienced and inexperienced group members need to understand each other's perspective and converge on a shared understanding in order to work together effectively.

Heterogeneity of group members becomes manifest in this setting in different dimensions, such as age, gender, formal education, work experience, duration of association with the company etc. In particular, we paid attention to the equal staffing of each group concerning members with much vs. little experience with the specific work task the group should document. 36 workers participated in the project, 5 females and 31 males. Experienced participants were on average 42.83 years old, inexperienced 23.06 years, with the youngest participant being 19 years old and the oldest 57. Total job experience of the participants reached from as low as 5 weeks up to 42 years.

***Table 1**. Demographics of heterogeneous participants*

	Non-Experienced	Experienced	Overall
Gender			
Female	4	1	5
Male	14	17	32
Total	18	18	36
Age			
Min	19	23	19
Mean	23.06	42.83	32.94
Max	30	57	57
Job Experience			
Min	0.1	1	0,1
Mean	5.3	23.25	14.53
Max	14	42	42

As heterogeneity is given in the project and shared understanding can be expected to be critical for the solution to the practical problem situation, it is well qualified as an action research field to explore the general phenomenon described in the introduction.

Action Research Approach

Shared understanding is a complex phenomenon in real world settings and no sufficient body of theory is available to explain the mechanisms leading to shared understanding, which could be used to guide design efforts. Therefore we chose an exploratory research design. Exploratory research allows the researcher to gather unexpected observations, examine the phenomenon in a holistic way and react flexibly to new insights. To allow for a holistic view and compensate for the weakness of individual data collection methods, a combination of several data collection methods has been selected. Action research has been chosen as research framework for the study.

Action research is a research approach from social sciences, where the researcher gets actively involved in the intervention and interacts with the members of the focal organization. On the one hand it aims at changing the social system and solving a concrete real world problem. On the other hand, new insights on the system and the phenomenon of interest should be gathered. (Baskerville 1999)

In a systematic cyclical process, the state of specific field situations should be understood and changed. Five phases are passed in an iterative, cyclical way, namely diagnosis, action planning, action taking, evaluation and specifying learning. In this paper, we follow the extended action research model by McKay and Marshall (2001), who make a distinction between problem solving cycle and a research cycle. The two cycle approach has been chosen to address the dual goal of action research and counteract the critics of lacking research rigor of action research. The research cycle aims at exploring the real world phenomenon of interest to gain insights on the theoretical research framework. It leads to answering the research questions specified in section one and helps building a theory or elements of new theory. The problem solving cycle aims at improving the specific real world problem situation by using a problem solving method to execute an intervention. In the study that underlies this paper, the problem situation exists in the challenge of supporting experience diverse work groups at a car manufacturing company to integrate and transfer their heterogeneous knowledge. The problem solving cycle results in a collaboration process design as the artifact that has been developed to change the real world situation. If the problem situation is related to the phenomenon of interest and is suitable to explore the phenomenon of interest, both cycles can benefit from each other. The dual approach is consistent with Briggs' (2006) claim to separate theory building research from the specific artifact/technological instantiation by defining separate research and engineering questions. The action research design and findings are described in sections three to seven. The piloting project with six teams allowed executing six iterative cycles.

Diagnosis

In the diagnosis phase, the problem situation is identified and the phenomenon of interest is specified.

Real World Problem Situation

From a problem solving perspective, the specific real world problem situation in the organization is diagnosed. In close interaction with the client organization the goals and general requirements for the piloting project are defined. From a practical point of view, this project aims at engineering a collaboration process design to improve knowledge integration and knowledge transfer concerning complex handcraft work processes within diverse work groups. In a series of three workshops, groups of six tool and dye makers should document a specific work process and develop learning material for new employees. The collaboration process needs to be standardized enough to be transferred to and executed by the organization at a later stage. In parallel to solving this specific problem situation, the project enables us to examine the more general problem of shared understanding in heterogeneous groups, as the groups are very diverse in their background, gender, age and work experience. While the practical solution includes further goals, e.g. producing the learning material as an artifact, shared understanding among the team members on the work process can be assumed as one central aim. Therefore, this pilot project seems suitable for exploring shared understanding from a research point of view.

Initial Research Framework

From a research perspective, we want to examine mechanisms leading to shared understanding in collaborative work. We are interested in analyzing how those mechanisms can be evoked by specifically designed collaborative practices. This research goal is based on the assumption that shared understanding is a dynamic state, which changes through the course of collaborative interaction due to certain mechanisms and that those mechanisms can be influenced to some extent by design choices (Bittner and Leimeister 2013). According to McKay and Marshall (2001) an initial research framework should guide the development of first design hypotheses. The collaborative practices we discuss in this paper are grounded on van den Bossches (2011) model of construction, co-construction and constructive conflict as mechanisms leading to shared understanding. Grounding on group cognition research from learning sciences and organizational sciences, van den Bossche et al. (2011) examined three kinds of team learning behaviors. They tested the effect of construction, co-construction and constructive conflict on the development of shared mental models. Furthermore, they measured how shared mental models mediate the effect of team learning behaviors on team performance.

Construction of meaning is referred to as "when one of the team members inserts meaning by describing the problem situation and how to deal with it, hereby tuning in to fellow team-members. These fellow team-members are actively listening and trying to grasp the given explanation by using this understanding to give meaning to the situation at hand"(Webb and Palincsar 1996).

Collaborative construction (co-construction) is "a mutual process of building meaning by refining, building on, or modifying the original offer in some way" (Baker 1994). Construction and co-construction lead to mutual understanding. However, mutual understanding does not yet mean that group members share one perspective or are able to act in a coordinated manner. As our definition of shared understanding involves a "meaning in use" aspect, mutual agreement on one perspective is furthermore necessary to achieve shared understanding.

Mutual agreement is achieved through constructive conflict, "dealing with differences in interpretation between team members by arguments and clarifications" (Van den Bossche, Gijselaers et al. 2011). Following van den Bossche's model, collaborative groups should express, share and listen to their individual understanding (construction), discuss and clarify them to reach mutual understanding (co-construction) as well as controversly negotiate an agreement on a mutually shared perspective (constructive conflict).

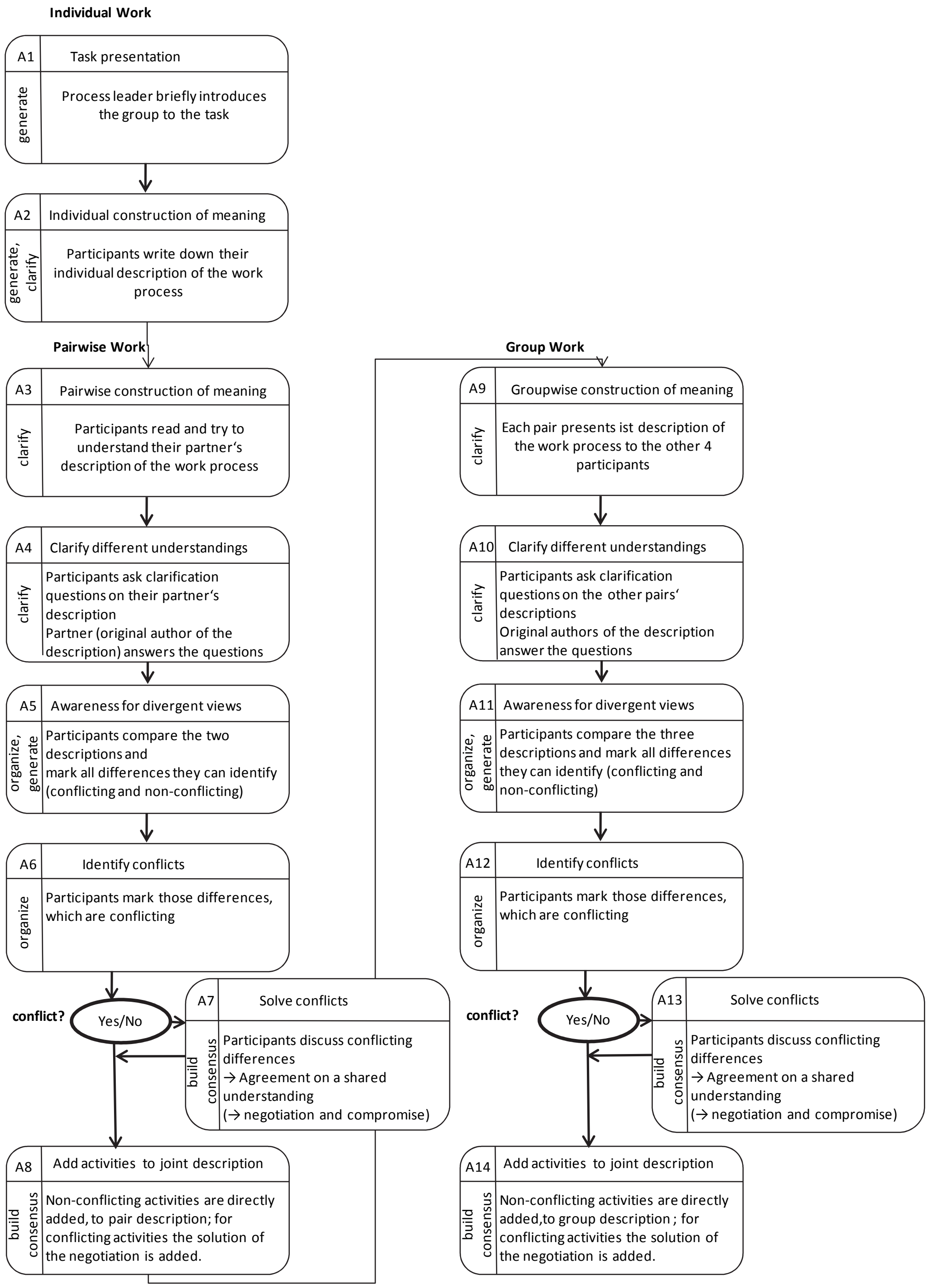

***Fig. 1**. FPM of Collaboration Process Design for the Construction of Shared Understanding*

Collaboration Engineering as Problem Solving Method

In the diagnosis phase, Collaboration Engineering is chosen as the problem solving method, as it aims at developing reusable collaborative practices for high value recurring tasks that can be executed without the ongoing intervention of a professional facilitator (de Vreede, Briggs et al. 2009). This matches the demand of the organization for a solution which can be transferred from the researchers who engineered the pilot process to the organization itself. The collaboration process design should be piloted, tested and documented for its future use by practitioners.

Action Planning

Intervention Planning to Improve the Problem Situation

In the action planning phase, the intervention to improve the problem situation is developed. We use the Collaboration Process Design Approach (Kolfschoten and De Vreede 2009) to implement the goal (improve knowledge integration and transfer in the group while documenting work processes collaboratively) in a collaboration process design. We split the collaboration process into a series of three one day workshops with homework activities in between the workshops. Only the first workshop is discussed in this paper, as these activities are dedicated to creating shared understanding of the sequence of activities required in the work process and we focus on examining shared understanding here.

The workshop is characterized by three main phases, (1) an individual description (draft) of the craftsmen's work process, (2) integration of the individual drafts in pairs of two and finally (3) the integration of the pairwise drafts in one solution that all six group members commit to. This structure reflects the need for a shared representation of the sequence of activities in the work process at the end of the first workshop. The individual phase is based on the assumption, that an individual working space and individual reflection is critical, as members need to be aware of their own mental model. An individual representation should help by encouraging individual construction of knowledge, reflection and can serve as a boundary object and reminder of the aspects to discuss in the pairwise phase. A pairwise phase has been included between individual and group work to foster the exchange between experienced and inexperienced participants. While in a larger group experienced members could easily take over the discussion and less experienced or less extroverted people might resign from contributing to the group product, in pairs of one experienced and one inexperienced member, both perspectives are likely to be heard.

Both collaborative phases (pairwise and group) are further divided into three activities each according to the three learning mechanisms proposed by van den Bossche et al. (2011). First, the participants try to make sense of the documents for themselves by reading their partners or groups work process description. Second, clarification questions are collected and answered to foster the co-construction of meaning and the evolution of mutual understanding. However, mutual understanding is not sufficient for coordinated action, meaning the collaborative development of learning material based on a shared understanding of the work process. As the two (or three in the group) drafts may still differ or even contradict each other in certain aspects, a third activity aims at evoking constructive conflict. Participants are asked to identify and resolve differences as well as conflicts in a discussion, before integrating their drafts into one that all agree on. A detailed description, how the specific activities are grounded in the theoretical framework of the team learning behaviors can be found in (Bittner and Leimeister 2013). Figure 1 shows the collaboration process design in a facilitation process model (FPM) notation. In combination with a short introduction and a wrap-up, this process design is the basis for the first workshop day with six groups of six employees each from a car manufacturing company.

Choice of Data Collection Methods

For the research cycle, the data collection methods are selected in the action planning phase. In order to allow for a holistic exploration of the phenomenon of interest, a structured survey before and after the workshop is combined with field notes of the moderator and facilitator as well as a content analysis of the artifacts that evolve during the collaborative work. Those artifacts, the work process descriptions, are interpreted as individual, pairwise and group cognitive maps.

Action Taking

In the action taking phase, the planned intervention is executed in the field. The researcher interacts directly with the participants and actively gets involved in the changes introduced to the problem situation. For the problem solving cycle, this means that the artifact – in our case the collaboration process design – is pilot tested. Six pilot workshops are executed with groups of six tool and dye makers each. Every workshop lasted for seven hours with a lunch break and several smaller breaks. They took place in a university collaboration laboratory to release the participants from their daily routine and were moderated by one of the authors. Another collaboration engineering researcher facilitated and observed the workshop process. As the action research approach demands an iterative development of the solution, the full cycles where run through for every group and necessary adjustments were made to the process design after each cycle. Data for gaining new insights on the problem field as well as on shared understanding as the phenomenon of interest where collected throughout each cycle. We will present these results and insights in an aggregated manner in the following sections.

Evaluation

In the fourth phase of the action research cycle, it is evaluated whether the intervention has had the intended effects and whether those effects were able to improve the problem situation. In particular we examine if the participants showed the three group learning mechanisms construction, co-construction and constructive conflict in the course of the collaborative process, that the collaborative practices were meant to evoke. Furthermore, we analyze whether shared understanding increases throughout the process and how the mental model of the work process of the participants changes towards a joint representation. For the problem solving cycle, the evaluation provides information in how far the intervention reached the goals that were set for the project, e.g. concerning knowledge transfer, group cohesion or satisfaction of the participants. The practical evaluation provides indication for the adjustments to the design that are necessary in the next problem solving cycle as well as when the action research project can be closed. For the purpose of this paper, we focus on the evaluation for the research focus of the project. In addition to new knowledge on the research frame, insights on the phenomenon of interest are gathered. Every instantiation serves the advancement of the collaborative practices for building shared understanding in heterogeneous groups.

From a theoretical point of view, two major issues have been assessed. First of all, it is of interest, if the applied collaboration techniques were able to evoke the three team learning mechanisms (construction, co-construction and constructive conflict), as they have been identified as determinants for shared understanding. Table 1 shows the average values on all three learning behaviors on a 7 point Likert scale among all 36 participants that were measured using the items proposed by van den Bossche, Gijselaers et al. (2011) (1=do not agree at all, 7=fully agree). It can be noted, that all constructs got very high ratings, significantly above the neutral value 4 in a one-sample t-test (T), while no significant differences between experienced and inexperienced participants or between different teams could be detected.

Table 2. *Team Learning Behaviors (7 point Likert response format, ***p<0.001)*

	Average	N	SD	T
Construction	6.3889	36	0.61075	23.468***
Co-construction	6.1481	36	0.66402	19.411***
Constructive Conflict	5.9375	36	0.70553	16.477***

As the team learning behaviors are only means to evoke shared understanding in the theoretical framework we use, the change in shared understanding has to be monitored as well to assess the effect of the techniques. We collected to self-assessment measures of shared understanding in a survey questionnaire in the beginning and in the end of the workshop. Shared knowledge has been assessed by the question "To what extent does your group have similar knowledge on [name of the work task that should be documented]?" (1=none; 5=very much). Differences in knowledge were assessed by the question "To what extent does your own knowledge on [name of the work task that should be documented] differ from the knowledge of your fellow team members?" (1=not at all; 5=very much).

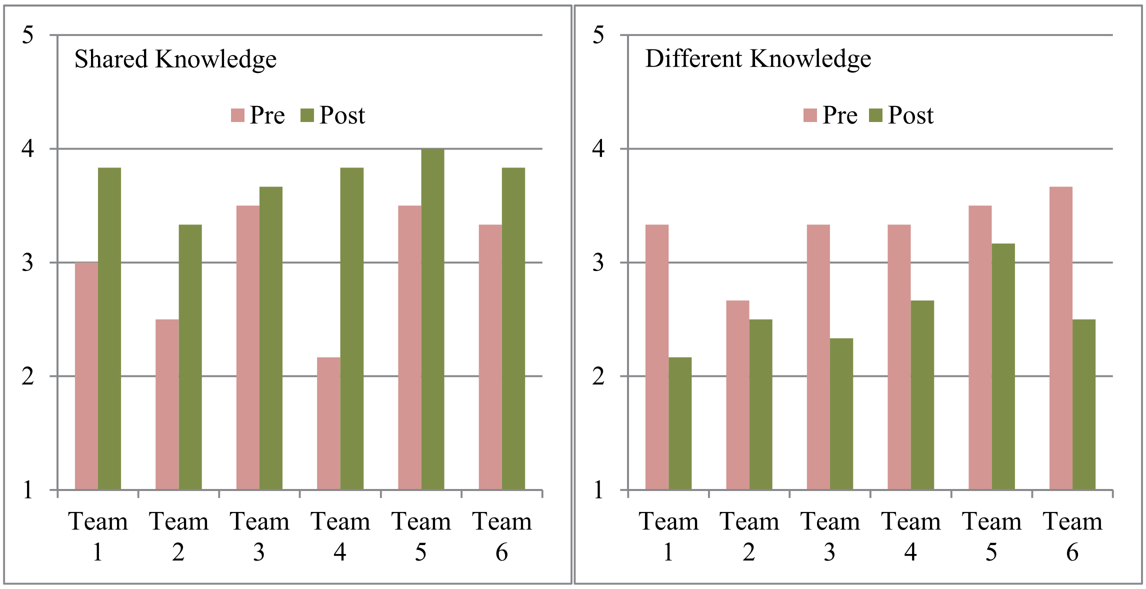

Fig. 2. *Changes of Shared Knowledge and Different Knowledge*

Figure 2 shows that, however, the teams started with different levels of perceived shared knowledge and different knowledge, all teams experienced a substantial improvement of those measures. Table 3 displays, how the measures for shared knowledge and different knowledge among the members of each group change from pretest to posttest. Shared knowledge increased significantly from a mean of 3.0000 to 3.7500, while differences of knowledge decreased from 3.3056 to 2.5556. This self-assessment of the participants goes in line with our expectation, that construction, co-construction and constructive conflict in the collaboration process are related to an increase of shared understanding.

*Table 3. Changes in Shared Knowledge and Different Knowledge (5 point Likert response format, ***p<0.001)*

		Average	N	SD	Change	T
Shared Knowledge	pre	3.0000	36	0.71714	-0.75000	5.147***
	post	3.7500	36	0.64918		
Different Knowledge	pre	3.3056	36	0.88864	0.75000	4.652***
	post	2.5556	36	0.84327		

As self-assessed changes in shared understanding may be biased and only reflect a perceived development, we used the changes in the work process documentation the participants generated throughout the workshop as a complementary method to evaluate the evolution of shared understanding. Table 4 reports the number of unique activities mentioned in the work process documentation by each individual after activity A2 (Fig. 1), pairwise after A8, (Fig. 1) and group document resulting from A14, (Fig. 1), e.g. “retrieve data”, “roughen component” etc. Furthermore, the increase (+) and loss (-) in number of constructs from individual to pairwise and from pairwise to groupwise documentation is displayed. This evaluation is based on data from five teams, as we changed the form of process documentation after the first team to improve clarity and process smoothness, which hindered comparability of the documents.

Table 4. *Changes in Mental Models – Number of Constructs in Work Process Documentation*

		individual	pair-individual	pair	group-pair	group
Group 2	non-exp. 1	15	+ 42	57	+ 28	85
	exp. 2	24	+ 33			
	non-exp. 3	0	+ 70	70	+ 15	

	exp. 4	15	+ 55			
	non-exp. 5	12	+ 37	49	+ 36	
	exp. 6	25	+ 24			
Group 3	non-exp. 7	52	+ 18	70	+ 9	79
	exp. 8	65	+ 5			
	non-exp. 9	48	- 1	47	+ 32	
	exp. 10	15	+ 32			
	non-exp. 11	44	+ 22	66	+ 13	
	exp. 12	55	+ 11			
Group 4	non-exp. 13	29	+ 36	65	+ 22	87
	exp. 14	49	+ 16			
	non-exp. 15	17	+ 36	53	+ 34	
	exp. 16	26	+ 27			
	non-exp. 17	16	+ 22	38	+ 49	
	exp. 18	36	+ 2			
Group 5	non-exp. 19	57	+ 26	83	+ 23	106
	exp. 20	80	+ 3			
	non-exp. 21	39	+ 27	66	+ 40	
	exp. 22	31	+ 35			
	non-exp. 23	18	+ 46	64	+ 42	
	exp. 24	54	+ 10			
Group 6	non-exp. 25	60	+ 10	70	+ 13	83
	exp. 26	65	+ 5			
	non-exp. 27	54	+ 11	65	+ 18	
	exp. 28	57	+ 8			
	non-exp. 29	27	+ 23	50	+ 33	
	exp. 30	28	+ 22			

Specifying Learning

Formally the last phase of action research, the documentation and interpretation of findings is in fact executed continually throughout the process. Knowledge that has been generated in the intervention and evaluation can be applied immediately in the diagnosis phase of the next cycle due to the open, exploratory research design. Thus, we made several adaptations to the collaboration process design after the first cycle. First, the initial participants documented their work process on flipchart sheets. As participants frequently wanted to change the order of their sequence or wanted to insert further activities, later teams worked with individual paper cards for each activity in the work process. This visualization aid also proved better, when pair wise and group wise documentations were created, as it was easier for team members to make sure to consider all activities and saved time, as descriptions did not have to be built from scratch.

The second process adaption concerned an evaluation activity, which was initially executed after A9, but was left out in the revised design. Participants had been asked to reflect on the differences of their own pair's documentation in comparison to the other two. They should indicate on a Likert Scale, how much each other documentation conflicts with their own understanding of the work process. It turned out, that participants were not happy with this global level of evaluation and that we could not identify a recognizable impact on the further discussion. Therefore, it was omitted.

In further iterations, no major changes to the design had to be made. We observed that all teams acted relatively similar and followed the process design. Evaluation indicates that team learning behaviors could be evoked in every group and measures of shared knowledge and shared understanding developed positively. Several trends become apparent: First of all, in most cases the number of constructs increases substantially from individual to pairwise to group documentation. As participants showed commitment to their pair and group solutions, we come to the conclusion, that the understanding of the work process became more detailed and elaborate throughout the workshop. Even very experienced participants, who have been executing the work process for decades, were not able to explicate and write down all relevant process steps initially. New activities that had not been mentioned by any individual came up in the construction, co-construction and constructive conflict phases. This observation indicates that the team learning behaviors evoke mutual learning and that experienced participants can as well benefit from the collaborative effort due to questioning and reflection. Second, in most pairs, the experienced participants (exp.) contributed more constructs initially, while their less experienced co-workers (non-exp.) adopted more new constructs, when a pairwise description was developed. In two pairs of groups three and five, the non-expert contributed more than the expert. Both experienced participants noted in this situation, that they found it hard to explicate their knowledge and that they benefitted from the impulses and questions given by their colleagues. High values of pretest shared knowledge in both teams indicate that inexperienced members of those teams already had an idea of the work process, which could be verified in interaction with the experienced colleague, who was thus fostered to explicate his knowledge.

We conclude that getting involved in the collaboration process as it is described here led to construction, co-construction and constructive conflict as well as more shared understanding among the team members. Inexperienced participants in general started with less detailed mental models of the work process, which were refined and complemented within the collaborative phases. Experienced participants had more advanced individual documentation, but gained further insights from the different approaches of their colleagues. Especially, they reported that the critical questions by inexperienced colleagues made them think about how to explicate their tacit knowledge. Furthermore, some of them reported that the interaction made them aware of some activities they forgot to document as well as of the existence of different approaches within their work group. The formal evaluation goes hand in hand with oral reports by several participants, who had the impression that they learned a lot from each other and that the group work was advantageous for their understanding.

Implications, Limitations and Future Research

To overcome the challenges in heterogeneous teams we used the action research approach to build a repeatable collaboration process to improve shared understanding.

The evaluation showed that the team learning behaviors construction, co-construction and constructive conflict occurred as intended. That leads to the conclusion that the applied collaboration techniques are a good means to evoke mechanisms leading to shared understanding. Furthermore, shared understanding could be increased, which became evident in the self-assessment of the participants as well as the changes in the working documents that reflect participants' mental models of the task. Both are indicators that the collaboration process design works and has the intended effects. Pairing of experienced and inexperienced co-workers seems advantageous for mutual learning.

This paper contributes to Collaboration Engineering practice by solving a specific problem in the organization and developing a pilot collaboration process design for shared understanding. The general process design can assist practitioners in building shared understanding in heterogeneous group work settings for complex tasks. Furthermore, we contribute to collaboration research by applying van den Bossche et al.'s (2011) model to guide design efforts. The application gives first insights on the mechanisms leading to shared understanding in groups of experienced and inexperienced workers.

However, the findings need to be interpreted in the light of exploratory action research design. The study was executed in one specific real world setting. Future applications in different settings could add to the understanding of mechanisms leading to shared understanding. For example, different combinations of experienced and inexperienced participants could be compared to identify an optimal degree of heterogeneity or different types of diversity could be explored. While the focus of this paper was on qualitative exploration of the phenomenon and design, data on shared understanding and team effectiveness, which has been collected after the workshop, should be used in future work to test the causal model. In this course, the assessment of the individual and team cognitive maps should be further extended. As work process documentation was mostly linear in the case at hand, we focused on the number of constructs, and excluded order and structure. They should be included in future research. In the real world situation, no control group was available to test for other influences than by the deliberate design choices. Therefore, no direct attribution of team learning behaviors to individual activities and design choices is possible at this stage. Also, alternative influences on the observed behaviors and shared understanding could not be controlled for, such as e.g. the influence of time spent together. Evaluation of the isolated collaboration techniques in an experimental setting could overcome those limitations in future work.

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