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Abstract. This paper introduces collaborative reflection for the purpose of team learning at the workplace and describes requirements for its computer support. In particular, we identify three processes to be supported and discuss solutions necessary for collaborative knowledge construction and meaning making based on captured teamwork data. This includes support for articulation work, transfer of established scaffolding and guidance concepts to the scope of reflection at the work place, and strategies of convergence for collaborative knowledge construction. Additionally, the paper outlines potential technical solutions embedded into organizational procedures to facilitate collaborative reflection and team learning.

Keywords: Reflection, collaborative reflection, collaborative knowledge creation, team learning, workplace learning

1 Introduction

Employees learn far more from experience than through formal training ([1], [2]). Reflection on own work practice has been identified as a central learning mechanism ([3], [4]) leading to a better understanding of own work practice and guiding future behavior ([5], [6]). Reflective learning at work supports the emergence of more flexible working routines and thus enables higher performance at work. Since in most organizations people work together in teams, research should consider *team learning by collaborative reflection* more comprehensively. This paper describes methods and tools to support collaborative reflection for team learning at the workplace. The work described here is part of the project *MIRROR - Reflective Learning at Work*[1].

2 The Significance of Collaborative Reflection for Team Learning

Most models of reflection have a strong individual focus (e.g. [3], [7], [8]). The social dimension of reflection has only recently been described by [9], who highlights the

1 MIRROR is funded under the FP7 of the European Commission (project number 257617). Further information can be found at http://www.mirror-project.eu.

role of sharing experiences for the purpose of learning (see also [10]). In this context, joint discussion of experience is considered to stimulate and deepen individual reflection. Other social activities such as asking for feedback on own work and social comparison processes have also been identified as important aspects of reflection ([11], [12]).

Many definitions of team learning explicitly include the notion of reflection, defining it "an ongoing process of reflection and action" ([13]). Understanding learning as co-construction of knowledge ([14]), "team learning occurs when individuals share their experiences thus, contributing their unique contextual knowledge to the team" ([15]). Thus, explication of individual experiences and understandings collaborative reflection can lead to a deeper insight into shared work practice. This is illustrated by a team learning scenario we observed at a SMB IT consulting company in Germany during extensive user studies within the context of MIRROR:

> In a company selling software for customer relationship management, sales consultants regularly visit trade fairs to present their products. Here they meet with their customers and get in touch with interested parties.
> Some days after visiting another fair, back at the headquarter, the consultants met to review the trade fair. This meeting started with a reporting session, where every participant described his or her very personal impressions of the fair. The team discussed about customer meetings, topics they encountered and feedback they received. Other consultants asked further questions such as whether talks worked out as planned, whether they achieved their goals, or how the fair will affect the upcoming contracts.
> In addition, more general questions were raised, mainly by the head consultant. He also made notes about any reports and stimulated discussion about similar experiences with customers. Once, for example, she asked whether and how cloud computing was discussed by the customers. This was commented during a lively discussion by other employees, who contributed various stories about their experiences. Others reported on articles about the topic they have read and offered to send around. The team also discussed the perceived relevance of cloud computing on the market, and whether they see it as a market trend or just as hype with no influence on the market. After some discussion, they conclude that the topic is indeed relevant for their company and has to be discussed further. However, due to the different experiences they had with customers, the team still could not decide whether or not they should take it into account for designing new products.
> Finally, the team started planning the upcoming trade fair and again discuss about cloud computing. They decide to use it cloud computing as an eye catcher at their booth. Thereby they hope to get into deeper discussion about cloud computing with customers and offer assessments of suitability for cloud products in the customers' environment.

As the story illustrates, potentials of collaborative reflection include learning from peers about their experiences, mutual assistance and reciprocal sense making, explication of individual understanding and integration of perspectives. It also shows the complexity of establishing a shared understanding in teams and the important role of shared material and experiences for this process. Our work aims at reducing this complexity and supporting the usage of data for reflection by computer tools.

3 Computer Support for Reflective Team Learning

As stated above, designing computer support for collaborative reflection is of vital interest for many organizations. Recent accounts for collaborative *learning* and *knowledge construction* might be helpful for collaborative *reflection* as well:

There are various approaches to support collaborative learning, including prompts for elaborated explanations, external representations for co-construction of ideas and means to make cognitive conflicts salient. Additionally, wikis (e.g. [16]), collaborative tagging systems (e.g. [17]), concept maps or systems for group discussions (e.g. [18]) have been applied successfully to support collaborative learning and knowledge construction. Additional, there are many concepts supporting discursive learning by contextual annotations of material ([19]), the coupling of chat and graphical data ([20]), guidance and scaffolding of knowledge building ([21], [22]) or negotiations ([23], [24]). However, while these approaches work well in educational settings, their value for collaborative reflection and workplace learning has yet to be analyzed as this context raises additional challenges, which we outline in the following.

4 Dimensions of Collaborative Reflection at the Workplace

Our approach transcends existing work on computer-supported collaborative learning with regard to two dimensions: First, only little is known about the applicability of concepts such as guidance or negotiation in workplace settings and for reflection purposes. Second, our approach uses data representing real teamwork practice. This raises questions which data to gather, how to do this and how to facilitate interaction with huge amounts of data.

4.1 The Context Dimension: Task and Social Aspects of Teamwork

Reflection on teamwork at the workplace refers to two levels of work done. First, it is about tasks to perform. Second, it addresses social demands of coordination and communication during teamwork. Thus, support for team learning through reflection must necessarily account for both task performance and social interaction. For both aspects, learning from past experiences is crucial for enhancing future performance of the team as well as individuals ([13]). Additionally, the task and social dimensions of team work also show the advantage of reflecting on team work collaboratively, justifying the extra effort stemming from collaborative reflection (cf. [11])

4.2 The Data Dimension: Teamwork Data as Basis for Collaborative Reflection

While formal learning can be supported by material, which has been decoupled from its real world context for educational purposes, workplace reflection needs data representing real work practice. Such data can enhance a team's awareness on shared

work practice and make problems or good practice visible. For this data, we need to consider a variety of different granularity and semantic levels. Table 1 shows a choice of such data, including data that might have been useful in the story described above (section 2) such as shared calendar entries to review the performance at the fair and coordinate time slots at the demo-system or notes developers took during the customers talks about topics like cloud computing. Additionally, it shows data such as stress levels of individuals, which at first sight does not support reflection. However, such data could be used in the scenario to determine stressful phases and thus support reflection on whether it was a challenging customer or a unknown topic that. Other data such as pictures, videos and workflow data can be helpful in reflecting individual performance or teams communication structure.

Table 1: Data types for reflection, with examples from the story above.

Type of data	Instance	Reflection purpose
Sensor data	Mood level measures	Spontaneous assessments
Workflow data	Duration of conversations	Analyze communication
Pictures and videos	Pictures from the fair	Recall / compare work practice
Application content	Shared library or bookmarks	Rebuild context of topic
Explicit notes	Notes from individual reflection	Explicate personal learning
Work documentation	Meeting minutes	Review conversations

Using data such as shown in **Table 1** for collaborative reflection not only needs means of gathering and aggregating data but additionally, people need to be supported in interacting with this data, e.g., in identifying relevant data, relating different data pieces to each other and making meaning from this data. Then, individual pre-understandings need to be shared. This results in a continuous cycle of interpreting data, collaborative sense making and sharing individual understandings. Obviously, this process cannot be supported solely by technology, but also needs corresponding organizational procedures, as we will explain in the next section.

5 Designing Computer Support for Collaborative Reflection

Collaborative reflection involves individual reflection, sharing individual pre-understandings, establishing a shared understanding and construction of knowledge. This is in line with Stahl's cycles of individual and collaborative learning ([25]), the co-evolution model of [16] and the conceptualization of distributed cognition by [26]. The challenges we described above and results from our empirical work grounded by observations and interviews conducted in 3 companies, show that support for these processes will at least need to include three crucial activities, namely the explication of experiences by means of articulation, guidance for negotiation and meaning making as well as support for convergence into joint knowledge:

Articulation support. Besides usual communication support, individuals need to be supported by means to comment on captured data and thereby articulate their understanding. Annotations on teamwork data stemming from such articulation work (cf. [27]) will then be used for reflection on this data material. In the story presented

above, available support for articulation could have helped team members to make their experiences of the fair explicit for discussion during and outside the meeting. For this purpose, we need to enable users to annotate data e.g., by textual comments, (semantic) tags and audio or video comments. Through annotations, a rich base of re-contextualized experience will be available for team reflection. For tool support of this process, we propose multimedia-enabled wikis, in which content can be easily linked, as a starting point.

Scaffolding and guidance support. Collaborative reflection might be hindered by communication and coordination barriers. Thus, it needs to be supported by scaffolds ([21]) and means of facilitation ([19]) in order to be successful ([11]). In our story the aggregation of topics from customer talks could have been supported automatically and possible discussion points prompted before the meeting. Obviously, this support cannot be done solely by facilitators but also needs tools such as prompts and proposals for actions, means for interrelating recorded material, visualization of processes and summaries of communications.

Synergy support. In order to help teams to derive implications for future team work from reflection, convergence of knowledge has to be supported, too. In the story above, convergence support might have helped to derive solutions faster and offer external sources that help assessing the relevance of the cloud computing topic. We suggest implementing support such as rating mechanisms for content, means for e.g. graphically structuring the content and tools negotiating meaning as support. Our initial approach will apply and evaluate voting and tagging mechanisms to support structuring of reflection material as well as to visualize relations.

6 Summary and Outlook

Our work intends to provide solutions for supporting collaborative reflection on captured teamwork data for the purpose of team learning. In this paper, we have shown that, although research on collaborative learning and reflection has produced valuable insights, it does not provide enough information to build proper tools for the support of collaborative reflection. We identified the articulation on shared experiences and teamwork data, the implementation of guidance for the generic scope of reflection and support for convergence to be processes of primary interest for collaborative reflection. For the application of these three processes to support collaborative reflection at the workplace, we aim at providing a socio-technical solution combining organizational processes with information technology. In order to accomplish these goals, further work will be focused on investigating processes of collaborative reflection and evaluating corresponding support in real world settings.

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