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Reflection Canvas – An Approach to Structure Reflection Activities in Engineering Design

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Abstract

Digitalisation affects all areas of organisations including processes, methods, tools, roles, or information flows and results in frequent changes with short intervals. In engineering projects (EP), new methods, and process improvement are important. Reflection, as a dynamic process between consciousness and activities (Jobst et al., 2020), has proven to enhance processes by offering benefits for team performance, team innovation and team effectiveness. In this paper, reflection is not aimed only at the solution but at the structured action and thus an active participation process of action. However, despite the high relevance and ongoing discussion about agility in engineering design, reflection as an agile method is rarely established in EP. While a plenty of reflection methods is described in the literature, only a few consider the entire Method EcoSystem (i.e. method use, context, design goals, information artifacts, and design outcomes) relevant when adapting and improving EP. To address the analysis and adaption of methods and design processes within existing Method EcoSystems, this paper considers the objects and process of reflection form an engineering point of view. Following a framework established in earlier work, a Reflection Canvas is proposed as a tool to raise awareness and structure and support reflection activities to implement new methods, adapt processes and improve collaboration in EP. Therefore, the analysis reflects on the tactical (development team) and operational (development team member) level and focusses on the three reflection dimensions *social*, *process* and *goal*. To assess the quality of the approach, we subjected it to a first practical test. The proposed canvas was evaluated to be helpful. On the one hand, the results illustrate the relevance of structured reflection in organisations. On the other hand, support for planning (e.g. in documentation or clarification of responsibilities) for implementation in everyday work is given.

Keywords: Structured reflection, process improvement, design learning, engineering design

1 Introduction

Globalization and digitalization trigger dynamic changes in technology, economy, organizations and social systems. With regard to product development (PD), these changes result in increasing system complexity, changing customer requirements and fast technology development as well as increasing product and market uncertainties (Boehm & Turner, 2004; Isaksson & Eckert, 2020). As a result, EP are more difficult to plan and often cause require second-order iterations and adjustments of ongoing projects (Inkermann et al., 2020). This infers that continuous process improvement is a fundamental requirement for business success of development organiszations (Hollauer & Lindemann, 2017; Reymen & Hammer, 2002). An essential success factor to cope with change in terms of agility is reflecting capacity of employees. Inkermann et al. (2020) describe reflection as a holistic process in which a engineering design team collectively and repeatedly reviews internal goals, strategies and processes. Despite the high relevance and ongoing discussion about agility in technical design, reflection is only marginally established in industrial EP. Inkermann et al. (2020) found that despite its importance, there is a deficit of strategic and systematic approaches to reflection in industry as well as a lack of corresponding methodological approaches in the literature (Inkermann et al., 2020). For reflection activities to be successful, it is important to reflect during the course of an activity (c.f. (Schön, 1987): *reflection-in-action* - to actively cope with complex situations, *reflection-on-action* - concentrate on the argument with the material of a situation at hand), to reflect on the right facts (c.f. Inkermann et al., 2020: defined dimensions of reflection, especially object of reflection) and to consult all persons involved in the EP in order to recognise changes and risks in time and to be able to react accordingly (Badke-Schaub et al., 2011). By providing a Reflection Canvas we focus on a strucutred process of reflection and take into account the awareness and the analysis activity in three essential reflection dimensions, namely *social*, *process*, and *goal*. In order to specifically investigate engineering design processes as a socio-technical system (Paulsen et al., 2020), we consider the entire Method EcoSystem (Inkermann, 2021) for planning reflection activities. The proposed Reflection Canvas is provided as a reflection tool for optimizing processes in EP.

1.1 Method EcoSystem – Product Development as a Socio-Technical System

In the digitalized and agile world, working conditions are changing due to technological innovations in PD. However, it has become clear that not only technical but also social systems are affected by changes. A socio-technical system is characterized by a common task (containing social and technical subsystems) that requires openness to the environment, flexibility and enables design in PD (Paulsen et al., 2020). Both the socio-technical system and the Method EcoSystem emphasize that digitalization cannot be considered in isolation from social aspects and that the effects can be shaped. Accordingly, both approaches are embedded in a superordinate system: (work) system (socio-technical system) or (method) system (method eco-system). The comprehensive interplay of processes, methods, tools, and organizational structures as well as cross-sectoral boundary conditions drive the main challenges in EP. Methods are used within the procedure of the development process and are to be understood as a prescription for performing individual steps in a targeted and efficient manner. A Method EcoSystem is defined as a system of methods embedded in an organization in which different design methods are used together and in which users can adapt and combine different methods according to their specific tasks (Inkermann, 2021). Evidence from both engineering design and prevention science suggests that method content and its relationship to the 5 factors - method use, context, design goals, information artifacts, and design outcomes - influence performance, especially when combined with continuous a structured reflection (Paulsen et al., 2020). For a

method to work, it needs to be understood in the context of all five factors mentioned above (Daalhuizen & Cash, 2021). However, there is currently no model for representing method content and its interactions that captures all five factors and their influence on method performance. Accordingly, it is necessary to find a starting point and support process control through reflection and learning. While the method content is stable as a support for developers, users, goals, information artifacts, and context are changeable. Accordingly, within a changing socio-technical system, it is important to view engineering design in PD as a continuous process in which regular and structured reflection occurs (Paulsen et al., 2020). In this paper, we refer to the concept of Method EcoSystem by looking at and reflecting on the interplay of methods, processes, tools, and organization in industrial practice EP.

1.2 Classification of Reflection Approaches

Reflection on an engineering design process covers reflection on perceived design situations and reflection on recalled design activities (Reymen & Hammer, 2002). Using reflection as a form of learning is a natural process that has been known for many years (Otte et al., 2018). According to Reymen & Hammer (2002), structured reflection is characterized by the following two criteria:

- **Regularity.** Reflection is carried out on a regular basis to identify and correct deviations from goals at an early stage.
- **Systematic.** Reflection is carried out systematically so that no important aspects are left out.

Different approaches to support reflection exist in terms of timing, level of detail, content, and process steps. A general distinction can be made between, conceptual models of reflection that describe abstract theories and generic procedures of reflection that serve as a general explanation of reflexive practice (Inkermann et al. 2020). Table 1 classifies the basic reflection approaches and highlights their *Reflection Focus* and the means used in each approach.

Table 1. Classification of Reflection Approaches in Engineering Design based on Inkermann et al. (2020).

Classification of Reflection Approaches in Engineering Design				***Reflection Thinking Process***		***Reflection Level***	
Reflection Approaches	**Summary**	**References**	**Reflection Focus**	***Awareness***	***Analyzing***	***Tactical***	***Operational***
Conceptual Models of Reflection	Describe reflection as an essential activity to acquire expertise	Schön (1987)	Reflection-in-action and reflection-on-action		•		•
		Kolb (1984, 2015)	Experimental learning within life cycles		•	•	•
		Boud et al. (1985)	Experiential and emotion-driven learning process		•		•
		West (1996)	Team reflection approach		•	•	•
Generic Procedures for Reflection	Provide information on how reflection can be organized and how reflection practice can be implemented in enineering design	Gibbs (1988)	Offers practical guidelines and guidance for reflective learning processes	•			•
		Hutterer (2005)	Reflection dialogues to identify the need for methodological support in product development	•			•
		Lindemann (2009)	Questions to stimulate the designers' self-reflection		•		•
		Reymen (2001)	Reflection for the improvement of processes, results and competences of individuals and teams	•		•	•
		Weixelbaum (2016)	Team reflection and the training of reflection skills in product development teams	•		•	•
		Geis & Birkhofer (2009)	Tool for designers that supports the systematic reflection of their actions		•	•	•

The column *Reflection Thinking Process* distinguishes whether the reflection is *Awareness* or *Analyzing*. As shown in Figure 1 (Section 1.2), Awareness includes (knowledge, motivation, expectation), while activity refers to Analyzing (dimensions: social, process, goal) at tactical and operational levels of reflection (column: *Reflection Level*), to which the further investigations refer. Following the classification of Jobst et al. (2020), a further distinction into

a two-stage reflection process is made to identify patterns of activity where consciousness indicates a new cue (Jobst et al., 2020). Based on the classification of reflection approaches, a framework of reflection can be derived. The reflection thinking process defines basic steps for structuring and the reflection level defines the time frame and an initial planning basis for the reflection process.

1.3 Objectives and Focus of Research

To be able to recognize challenges in EP and to achieve process improvements, it is necessary for teams to reflect regularly and systematically. Although this need is well known, in practice often there is only a reaction and action instead of taking advantage of systematic, structured reflection (Otte et al., 2018). This paper examines on the one hand, how industrial practice retrospectively assesses process and outcome. On the other hand, it examines the objects of reflection at the tactical and operational levels and derives measures for planning activities. This leads to the following research questions:

1. *What is a useful structure of a reflection process (starting from awareness) for users who are not yet practiced in reflection?*
2. *Which planning activities and measures do support structured reflection in EP?*

To answer these questions, existing methods for reflection are analyzed (Section 2.1) and a taxonomy for planning and analyzing reflection in EP is presented (Section 2.2). Subsequently, methods for reflection based on literature are pointed out. In addition, reflection workshops (Neininger & Kauffeld, 2009) are conducted in industrial practice related to reflection on methods of engineering design. Section 3 introduces the *Reflection Canvas*, a reflection tool for structured planning of reflection activities, and describes its structure and selected guiding questions. Then, the approach of the Reflection Canvas in industrial practice is presented with exemplary results from first uses of the tool in EP (Section 4).

2 Literature based Analysis of Reflection in Engineering Design

2.1 Reflection as a Learning Process

For a structured adaption of the Method EcoSystem, the concept of team reflexivity has been relevant for some time. It was originated by Schön (1987) - i.e., reflection-in-action, reflection-on-action. West (1996) defines reflection as a deliberate and purposeful process in which individual team members or teams recapitulate their experiences within a particular situation (goals, strategies, processes) and reevaluate them in the current context to guide and adjust future actions. Reflexivity in teams can be described as an iterative, three-step process (action/adaption, reflection, planning) that is repeated in reflection cycles over several work phases (Gabelica et al., 2014; Konradt et al., 2016). In this paper, we adapted the original model by West (1996) using the model proposed by Jobst et al. (2020; c.f. Figure 1) to expand on reflection by adding componenents of awareness (i.e. a background control system continously ensuring a situation does not deviate from the expected situation) and activities (i.e. gaining a better understanding of a situation). In a first step (reflecting), team members evaluate current internal goals, performance shown so far, and strategies applied using feedback as well as knowledge, motivation and expectation (i.e. awareness; Jobst et al., 2020). This helps to identify the reasons for successes and failures in the collaboration (Kauffeld et al., 2019). Next, the team reflects on alternative solutions to tasks and problems they have encountered by analyzing and reflecting on the situation in the three dimensions *social*, *process* and *goal*. In the second step (planning), the team determines specific alternative actions and options with which to confront future challenges (Gabelica et al., 2014). In the third step (adapting), previously agreed upon changes and actions are implemented before the cylce starts again. Thus, the overall model

depicts reflection as a circular and constantly repeating process of learning and adaptation. The research pool on the effectiveness of this model shows positive effects on team performance (Villado & Arthur, 2013) and team effectivity (Widmer et al., 2009).

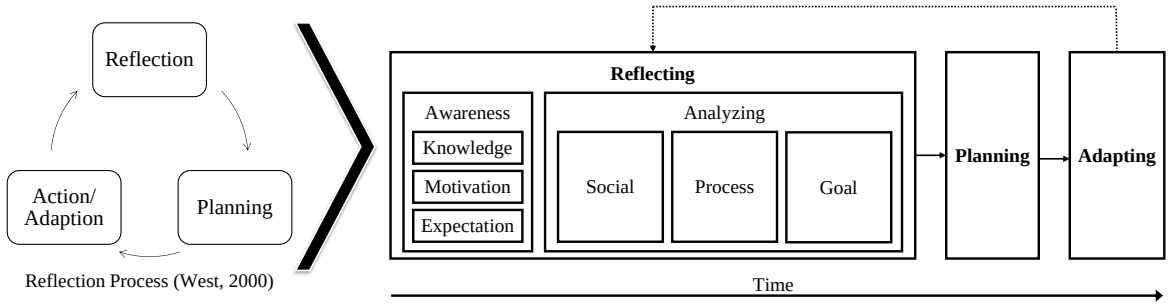

Figure 1. Original reflection process according to West (2000) (left) and proposed model of reflection based on Jobst et al. (2020) and West (2000) (right).

2.2 Taxonomy for Planning and Analyzing Reflection in Engineering Projects

In addition to reflection itself, adaptation processes are central to the concept of team reflexivity. West (1996) assumes that only reflective processes are insufficient and will not result in improvement. High levels of reflexivity are achieved only when a team passes the whole cycle that are the phases of reflection, planning, and action/ adjustment. In the collaborative reflection phase, team members become aware of current strategies, processes, problems, or failures and critically engage with them. Therefore, in this paper we understand reflection not only in the sense of evaluating products or project results, but also as a means to analyze methods used and processes given. (Seegrün, 2019; West, 2000) In order to explore current practice of reflection in industry, four industry partners within a research project were asked to describe approaches and scope of reflections. Therefore, based on the RECAP framework (Inkermann et al., 2020), a taxonomy was developed, c.f. Table 2.

Table 2. Taxonomy to analyse and plan reflection scenarios.

Parameter	Characteristic				
1 Process of Reflection	Technical Processes	Technical Management Processes			
2 Type of Reflection	Reflection during the Transition Phase (West, 2000)	Reflection during the Action Phase (West, 2000)			
	Extra Meetings / Item on the agenda	Through triggers / All the time / Unconscious			
3 Level of Reflection	Strategic reflection (organisational level)	Tactical reflection (team level)	Operational reflection (individual level)		
4 Targets of the Reflection (WHY)	Company-specific processes	Project-specific processes	Individual process steps		
5 Actors (WHO)	Top management	Middle management	Process management	Project management	Project team members
6 Object of Reflection (WHAT)	Social aspects (culture, collaboration, team, coordination, individual, communication)	Process (structure, technology, project, procedure, activities)	Goals (environment, strategy, product, partial results, task)		
7 Direction of Reflection	Retrospective	Simultaneous	Prospective		
8 Success of the Reflection	very successful	rather successful	rather unsuccessful	very unsuccessful	

This taxonomy serves as a tool to assign different reflection scenarios in relation to engineering processes. To define goals, identify actors and objects within the RECAP framework, they find selected guiding questions in Seegrün (2019). An exemplary guiding question is: "Along the development process, remember different reflection scenarios that you have experienced in projects in the last few weeks. When did they take place, how did they proceed, who was involved?" The taxonomy enables to classify and characterize the partner-specific scenarios

according to the criteria given in the taxonomy (c.f. Table 2). The eight parameters in Table 2 refer to the level of reflection (strategic, tactical, operational), the objects of reflection (dimensions: social, process, goal) and finally evaluate the success of the reflection process. The taxonomy provides an initial overview of the existing reflection planning and implementation activities in EP through its application in industrial practice. Documentation and action planning of past reflections would have been helpful to identify potentials and actively implement process improvements. The taxonomy provides the framework to start a successful structured reflection and ensure improvement in the next EP. The taxonomy supports the analysis of the reflection practice within an organization and generates the basis for the proposed Reflection Canvas.

2.3 Methods for Reflection

There is a wide range of methods to support reflection (e.g., discussions, journals, presentations, worksheets, special projects), which vary in their effectiveness depending on the target group and context (White, 2012). Following White (2012) and Otte et al. (2018), high quality reflection (i.e., profound instead of superficial content) in appropriate settings (i.e., a trusting environment) results in the highest performance improvements. On the method itself, Sturgill and Motley (2014) were able to show that guided, dialogic reflection was more effective than free private reflection. In the field of software engineering, there are several examples of reflection methods. For instance, Marques et al. (2018) use a version of Remote Weekly Monitoring. This is a monitoring method that uses self-reflection and shared learning to enable users to improve their own work processes by examining their own work and teamwork processes. In After Action Reviews, Geithner and Krüger (2008) use four guiding questions to reflect at regular intervals on the goal, performance, target, and performance variance as well as lessons learned. In line with the research by Sturgill and Motley (2014), questions to guide reflection (guiding questions) have become a widely used and easily applicable tool to foster reflection in the workplace (Fleck & Fitzpatrick, 2010). Another common approach to reflection in practice are checklists encompassing multiple aspects of reflection providing users with another easy and quick to use tool (Geis & Birkhofer, 2009). As a more complex reflection method, Inkermann et al. (2020) designed a comprehensive framework in which the reflection process can be run through in a structured manner. Finally, Jobst et al. (2020) developed the Reflections Canvas, a comprehensive tool that can support the reflection process through sketching, prototyping, and verbalization. In this paper, we use the rough structure of this model, based on West's (2000) reflection process and the findings of Inkermann et al.'s (2020) RECAP framework, as a guide to develop an engineering design-specific Reflection Canvas.

3 Proposed Reflection Canvas

3.1 Structure of Proposed Reflection Canvas and Support of Engineering Teams

The proposed Reflection Canvas (c.f. Figure 2) is defined as a tool that integrates all essential elements of a socio-technical system into a structured, scalable reflection framework. The Canvas is a visual tool that teams use to define and document key characteristics of a management object in the form of a pre-structured poster. The proposed Reflection Canvas is based on the principles of the Canvas method. The Canvas is a visual tool that teams use to define and document key characteristics of a management object in the form of a pre-structured poster. An established example is the Business Model Canvas (BMC) by Osterwalder. (Qastharin, 2016) The proposed Reflection Canvas represents the reflection cycle of West (2000) by forming the 3 main areas *feedback*, *reflection*, and *planning*. Furthermore, it distinguishes the 3 levels of reflection:

- **Strategic** (organisational): To derive company-specific reference process
- **Tactical** (team): Optimisation and adaptation of project-specific processes)
- **Operational** (individual): Addresses situation-specific adaptation of individual process steps

In the first phase, *feedback*, one is at the strategic level of reflection and reflects on the situation under consideration (e.g. pilot project: quality management process). In the second phase, *reflection*, a distinction is made between the tactical and operational levels of reflection. In each level, reflection takes place in the three dimensions (*social, process, goal*). The third phase, *planning*, is structured in the same way as the reflection phase and refers to action planning.

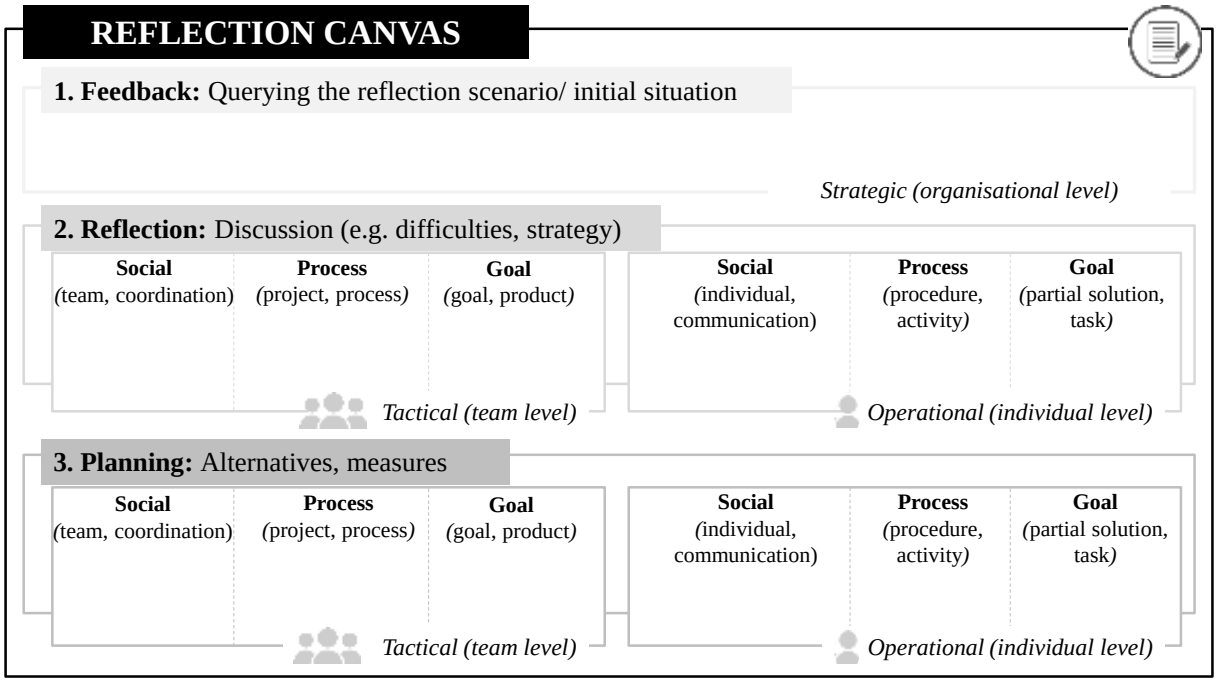

Figure 2. Reflection Canvas to structure reflection activities in engineering design.

The Reflection Canvas is designed to support development teams in conducting structured reflection. The developed tool is meant to serve as a template to immediately start the active reflection process in EP. The template for the procedure (c.f. Figure 2) should serve as a basis for documentation and planning of the reflection activities. By repeatedly using the reflection tool in different phases of an EP, reflection can be used as a learning process in both *reflection-in-action* and *reflection-on-action* (Schön, 1987). In particular, the Reflection Canvas serves as a simple tool that can be used across disciplines and provides engineering design teams with confidence in dealing with reflection and the derived planning measures for future EP.

3.2 Procedure and Guiding Questions for Reflection in Engineering Projects

The structure of the Reflection Canvas is based on several guiding questions arising from the taxonomy, c.f. Section 2.2, and the RECAP framework (Inkermann et al., 2020). The guiding questions refer to the objects of reflection. The Reflection Canvas is structured in such a way that, in relation to a selected example from EP, one works chronologically through the phases from 1 to 3 and the respective levels of reflection. For this purpose, selected guiding questions are provided, c.f. Figure 3. It starts with *feedback*, which is an introductory entry reflection asking for feedback on performance (e.g. What was achieved?) and process (e.g. How was the task completed?). At this level, external reflection, e.g. by management or external trainers, is taken into account. In the second step, we move on to the phase *reflection*, where the first part

reflects on the tactical level in the three dimensions (*social*, *process*, *goal*). The selected guiding questions are related, for example, to the team composition, the benefits/ challenges of the design methods used in EP or the achievement of goals. The second part reflects on the operational level. The guiding questions here are directed at difficulties in EP, the flow of information or helpful methods in EP. In the third step, the *planning* phase is also considered first at the tactical and then at the operational level of reflection in the three dimensions mentioned. The guiding questions refer to the measures and planning for future EP, such as tools, communication measures or new methods. The selected guiding questions are classified in the Reflection Canvas to provide a structure (c.f. Figure 3). In this way, improvements in future EP should be consciously perceived and documented. First exemplary results from practice from the reflection surveys with industry partners of a research project are explained in Section 4 and presented in the Reflection Canvas in Figure 4.

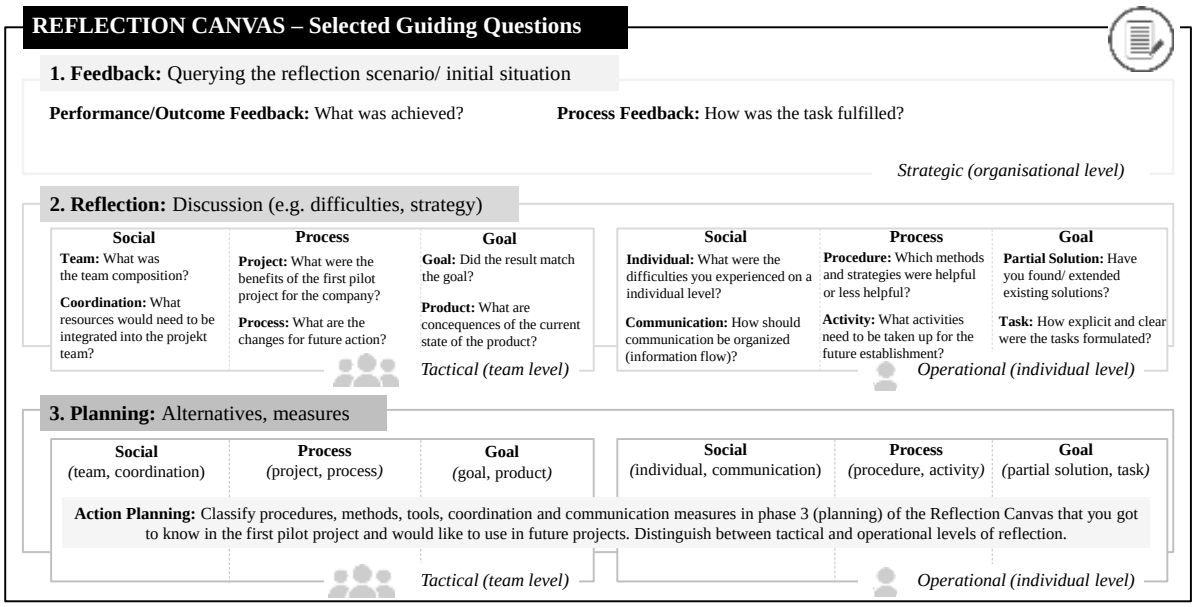

Figure 3. Structure and selected guiding questions in the proposed Reflection Canvas.

4 Case Studies

This section introduces exemplary results from first pilot projects (c.f. Figure 4) and describes the practical application of the Reflection Canvas. In two pilot projects (approx. 10 team members per team) with small and medium-sized (SME) partners from the mechanical and plant engineering sector, the Canvas was used to reflect on the methods, procedures, and decisions applied in EP. In the reflection taxonomy (c.f. Section 2.2), SME partners already assign reflection scenarios, which subsequently focus the level and object of reflection in the Reflection Canvas. Within reflection workshops, the three phases were approached in the form of an interview using the selected guiding questions from Section 3.2. As described in the taxonomy, the focus is placed on the objects of reflection (What?) and thus on the three dimensions (social, process, goal). Figure 4 summarizes the exemplary results of the industry partners from the SME environment and thus the answers to the selected guiding questions in the Reflection Canvas. The common ground was that the partners found the applied methods helpful in the development process and would like to continue using them. However, it is necessary to adapt the methods to the company-specific situation. Another commonality was that day-to-day business often ties employees up a lot of time, making it very difficult to introduce new methods. One difference among the SME partners in the dimension of goal was that in one pilot project the management has a central role in the overall company and the

development team is often restricted in its freedom of decision. This led to deviations in the goals and frequent adjustments during the development process. In the other pilot project, the development team was made up of several locations, which made standardization difficult. In the target dimension, this led to deviations in the presentation of results and the decision regarding implementation in management. As overall feedback on the reflection workshop with the approach according to the Reflection Canvas, especially the documentation and the planning of measures for future EP were evaluated positively.

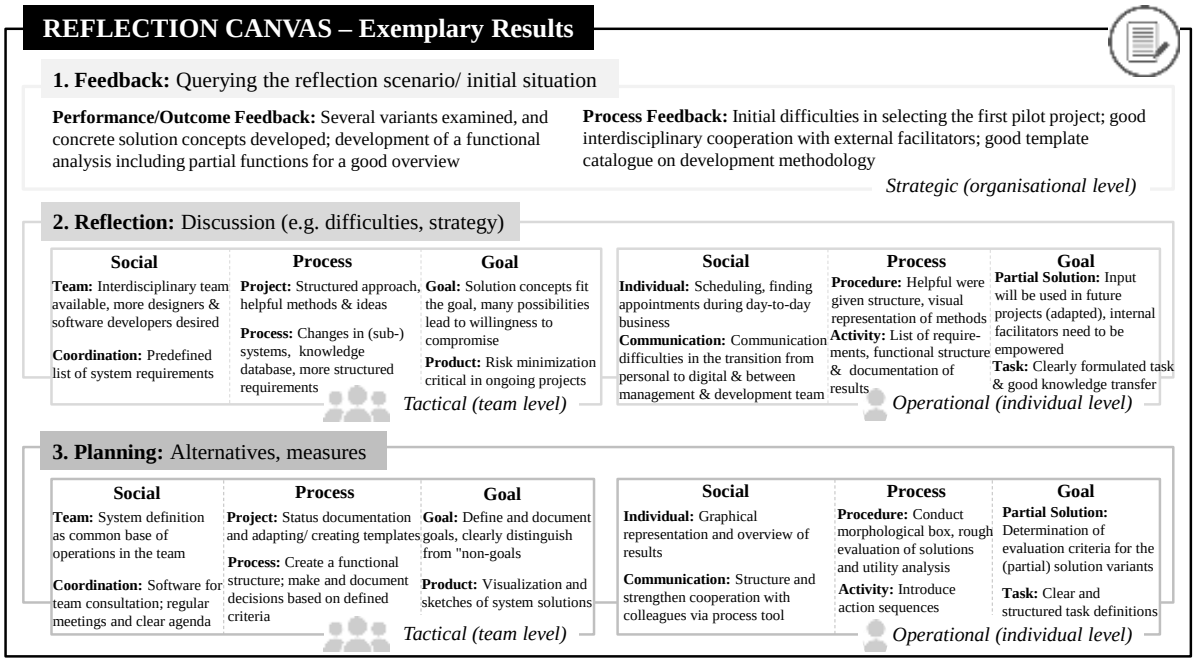

Figure 4. Proposed Reflection Canvas with exemplary results from 2 pilot projects in a SME environment.

5 Conclusion and Outlook

Reflection is of particular importance for planning and goal setting, when implementing and adapting processes and methods in EP. To analyse current reflection practices in EP and support the planning of reflection activities in EP, we propose a taxonomy comprising eight essential parameters and their corresponding characteristics. To provide a useful structure of a reflection process for users, it is important to build awareness in a first phase since the reflection process has to be done consciously (c.f. Figure 1). To guide the reflection for unexperienced engineers, we propose a procedure and three basic dimensions to be considered, that are social, process, goal. The taxonomy and the procedure form the basis for a first version of a Reflection Canvas to support the systematic reflection in practice defining three phases and guiding questions. The Reflection Canvas structures the reflection process but is limited in terms of a digitalised linkage of methods, processes, tools, organisation, and roles. The canvas is a first guide to conscious reflection and documentation of reflection results. In a second step, a linking of the interactions between the dimensions (social, process, goal) and methods or roles will be done. This analysis results in various activities that promote structured reflection and take into account the boundary conditions (needs, requirements, interfaces) of engineers. The procedure and planning of structured reflection must fit the team's field of activity and be accepted by the team. In further research, the canvas will be transformed into a model that links processes, methods, roles, competences, and information flows and offers user-specific choices in terms of reflection methods. For further development of the Reflection Canvas, a fundamental evaluation of this tool is needed at shorter intervals and across several organisations. It is

planned to evaluate the Canvas and adapt it in terms of depth and granularity to anchor the reflection process more firmly in EP and identify potentials for improvement in EP.

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