

# Improving Requirements Engineering by Artefact Orientation

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**Abstract.** The importance of continuously improving requirements engineering (RE) has been recognised for many years. Similar to available software process improvement approaches, most RE improvement approaches focus on a normative and solution-driven assessment of companies rather than on a problem-driven RE improvement. The approaches dictate the implementation of a one-size-fits-all reference model without doing a proper problem investigation first, whereas the notion of quality factually depends on whether RE achieves company-specific goals. The approaches furthermore propagate process areas and methods, without proper awareness of the quality in the created artefacts on which the quality of many development phases rely. Little knowledge exists about how to conduct a problem-driven RE improvement that gives attention to the improvement of the artefacts. A promising solution is to start an improvement with an empirical investigation of the RE stakeholders, goals, and artefacts in the company to identify problems while abstracting from inherently complex processes. The RE improvement is then defined and implemented in joint action research workshops with the stakeholders to validate potential solutions while again concentrating on the artefacts. In this paper, we contribute an artefact-based, problem-driven RE improvement approach that emerged from a series of completed RE improvements. We discuss lessons learnt and present first result from an ongoing empirical evaluation at a German company. Our results suggest that our approach supports process engineers in a problem-driven RE improvement, but we need deeper examination of the resulting RE company standard, which is in scope of the final evaluation.

**Keywords:** Requirements Engineering, Artefact Orientation, Empirical Design Science, Software Process Improvement.

## 1 Introduction

Requirements engineering (RE) constitutes an important success factor for software development projects, since stakeholder-appropriate requirements are important determinants of quality. Incorrect or missing requirements can greatly add to the implementation or maintenance effort later. At the same time, RE is an interdisciplinary area in a software development process that is driven by

uncertainty and is therefore highly volatile and complex. The first step for companies towards good RE is to establish an *RE reference model*, i.e. a company-wide definition of activities and modelling methods to be applied, roles to be assigned, and artefacts to be created. Once an RE reference model is established, it should be continuously improved to reflect, e.g. project experiences and the continuously evolving organisational culture.

To improve RE in industrial contexts, process engineers have to decide on whether to opt for a problem-driven improvement according to individual problems and needs or for a normative improvement, e.g. as part of an assessment in which companies are benchmarked against an existing norm [1]. Although we understand, especially in small companies, the reluctance against normative improvements [2,3], the high number of available RE improvement approaches still remains normative, solution-driven, or at least process-oriented. They are normative, because a pre-defined standard is taken to be the norm for RE processes; they are solution-driven, because the improvement skips a profound problem analysis and starts with a standard process definition that pretends to be a one-size fits-all solution and against which companies are too often blindly assessed [4]; they are process-oriented, because problems are assumed to consist of flaws in the current process and in the methods used for creating RE artefacts.

As a result, those RE improvement approaches encounter problems in practice [2]. RE is complex by nature and hardly standardisable with a norm, and the notion of RE quality depends, inter alia, on whether an RE reference model contributes to project-specific goals of a company. Starting with a predefined universal solution and attempting to analyse the gap with current practice may not lead to an improvement, because methods, related artefacts, and roles are added without regard for stakeholder-specific goals and problems of a company [5]. Therefore, improvements cannot be meaningfully implemented without a qualitative problem investigation that reveals which goals must be achieved [1,4] and which artefacts should be created in which way [5].

**Problem.** Although the importance of continuously improving RE in companies is recognised for many years, available approaches are either normative focussing on assessing and benchmarking companies against given norms, or they are at least process-driven. Yet missing is an approach to effectively guide a problem-driven analysis and improvement of RE while giving attention to the improvement of the RE artefacts in response to stakeholder goals.

**Principal Idea.** We propose to use a problem-driven approach that starts with an empirical study of the improvement problem, and that focusses on artefacts rather than on processes. We use the term “problem-driven” to indicate that we start with stakeholder goals and an empirical study of the improvement problem before initiating the improvement implementation. In our experience, the focus on RE artefacts benefits furthermore the analysis and the improvement of RE processes as it allows to objectively reproduce and analyse RE processes without having to take into account the variability of the RE processes reflected in the different projects of a company [6]. Our problem-driven approach implies that

we start from understanding the practice of modelling and documentation in a company, rather than from a normative view of how artefacts should be developed and structured in an ideal world. The RE improvement proposals based on this are more likely to consist of small, feasible steps jointly implemented with the stakeholders as part of a series of action research workshops, rather than of large, impractical leaps that will not be implemented, because they are, for example, too risky or simply do not fit their project demands [3,4].

**Contribution.** We contribute an *artefact-based RE improvement approach*, which has been developed over the last five years based on a series of completed bilateral research cooperations with industrial partners. We first introduce the underlying principles of an empirical engineering cycle used to steer problem-driven research, and the principles of artefact orientation. We present the RE improvement approach as a specialisation of the engineering cycle that aims at a problem-driven RE analysis and an improvement implementation by the use of artefact models. Finally, we discuss lessons learnt and first results from an initial empirical evaluation we are performing at a German company.

## 2 Fundamentals and Related Work

Software process improvement (SPI) is iterative by nature. Having its seeds in the known plan-do-check-act (PDCA) paradigm, it aims at continuously analysing problems/the current situation in processes as part of an appraisal, planning an improvement, implementing the improvement, and evaluating the improvement, before initiating the next iteration. In general, we can distinguish normative approaches and problem-driven approaches. Following the definition of Pettersson et al. [4], normative approaches are based on a prescriptive “collection of best practices [...] to be adhered by all organizations [...]” while “no special consideration is taken to an organisation’s situation and needs, other than how the development process compares to the one offered by the framework”. In contrast, problem-driven approaches are based on a “thorough understanding of the current situation [...]” whereas the choice of solutions is done according to problems identified in the organisation’s projects.

For requirements engineering process improvement (REPI), there exist mostly normative contributions [1] of which a prominent and representative one is R-CMM, a CMMI-based RE process improvement model by Beecham et al. [7]. Approaches of this category focus on a prescriptive benchmarking of the maturity of RE according to a specific norm. As they follow the process-oriented paradigm [8], they propagate a norm that consists of a set of activities and best practices (see [4]), each indicating to the need of producing some artefacts. Those artefacts, however, remain underspecified, i.e. companies have to define those artefacts in personal responsibility without any guidance or blueprint. The guidance on the actual implementation of the improvement is, in general, not in scope of those approaches as they focus on comparable benchmarking and the adaptation of a company-specific RE to that given norm by adding potentially missing processes, methods, or other resources. Although approaches of this category are frequently applied in practice and empirically evaluated in different

contexts [9], current studies do not provide evidence for the general benefits of normative approaches for the actual quality of a company-specific RE [2]. Those normative approaches often neglect company-specific goals and problems [3], whereas these goals determine the notion of quality, i.e. the extent to which a solution achieves a goal from a company's perspective [5].

In response to this shortcoming, current approaches focus on problem-driven RE improvement. They follow the evaluation and tailoring of solutions according to the particularities of single companies due to the sensitivity of RE to stakeholder goals and context phenomena. An example for approaches of this category is the iFLAP approach by Pettersson et al. [4]. They propose to conduct a process assessment and improvement by means of a specific set of empirical qualitative methods, such as interviews. In fact, qualitative methods are gaining much attention to investigate the sensitive contexts of organisations, their processes, and the people involved [10]. However, although there exist first valuable contributions that apply such methods in the area of SPI, they still do not rigorously cover the overall improvement life cycle and, thus, they do not close the gap left open by solution-driven REPI approaches. Furthermore, to the best of our knowledge, there exist no REPI approach that gives any attention on how to conduct an improvement taking into account the quality of the RE artefacts.

**Previously Published Material.** In [5], we presented first results on how to perform problem-driven RE analyses with a particular focus on artefacts to plan the implementation of an RE improvement in a problem-driven manner. However, we left open an understanding on how to apply empirical research to the whole improvement life cycle. In this paper, we will add these stages to define an approach to conduct a seamless artefact-based RE improvement covering the problem investigation and its implementation.

### 3 Artefact-Based Requirements Engineering Improvement

In the following, we show the principles of design science and artefact orientation, before contributing our conceptual framework for problem-driven, artefact-based RE improvement.

#### 3.1 Design Science Principles

Design science is the design and investigation of artefacts for useful purposes. As illustrated in Fig. 1 (middle part), it consists of two activities, practical problem solving and knowledge question investigation, each with their own context [11].

By a practical problem, we mean a problem to change real world phenomena so as to achieve stakeholder goals; for example, to improve RE. We will call a solution proposal to a practical problem a *treatment* to emphasise that problem solvers treat a problem without guarantee of a complete solution. The treatment is designed and validated by the design scientist and will consist of a modelling technique, notation, or an artefact that helps stakeholders to achieve their goals. In design science context, the socio-economic context (left-hand side of Fig. 1) is, e.g. a software engineering department that wants to improve RE performed at the various projects of a company.

Problem solving may lead to knowledge questions, such as the question what the problematic phenomena are, or what the properties of a proposed solution should be. This leads to the other design science activity, answering knowledge questions (right-hand side of Fig. 1). To answer these questions, we use a knowledge base of published knowledge, in our case SPI knowledge.

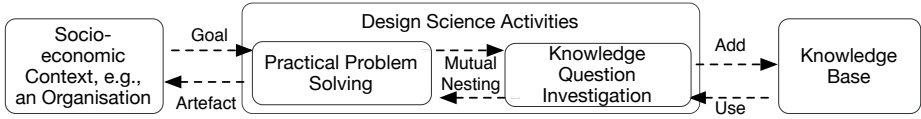


Fig. 1. Design science framework

Conversely, validated answers to our knowledge questions, to the extent they are not confidential, can be published and added to the public knowledge base. In some cases, answering a knowledge question generates a new practical problem, such as the problem to build observation instruments, or to run a pilot project to test an artefact. In this way, the design scientist may jump between the two main design science activities of Fig. 1.

We postulate that any rational improvement attempt requires problem investigation, treatment design and validation, implementation, and evaluation. We call this the *engineering cycle* (Fig. 2), which can be considered as a specialisation of the PDCA cycle (see Sect. 2) and which logically structures the practical problem solving task shown in Fig. 1. During *problem investigation*, the design scientists ask who the stakeholders are and what goals they have, what problematic phenomena there exist and what their effects are, and what this means for the goal contribution. All these questions are of empirical nature and no treatment design is done.

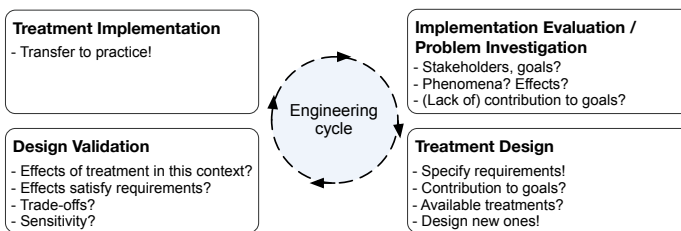


Fig. 2. The engineering cycle

*Treatment design* consists of two sets of design choices, indicated by exclamation marks, and two knowledge questions, indicated by question marks. The first design choice to be made is the specification of requirements for a treatment. These could be, for example, requirements for artefacts used in the treatment. The difference with the goal analysis is that requirements are desired properties of the treatment, whereas goals are states of the world that stakeholders want to achieve. The design scientist thus infers sets of requirements that could achieve

the elaborated stakeholder goals. The contribution question asks for an argument why a treatment that satisfies these requirements would contribute to the satisfaction of the stakeholder goals. Once we are sure enough about the requirements for a treatment, we can make an inventory of available treatments that satisfy these requirements. With this information, the design scientist designs a treatment for the case. This is an integration of elements of available treatments, possibly with newly designed elements expected to be effective for the case.

In *design validation*, the design must be investigated to see what its effects will be in the case, and whether this will satisfy the requirements. A comparison with alternative treatments must be made (trade-off analysis) and sensitivity to changes in the problem context must be investigated. *Treatment implementation* in the engineering cycle is the transfer to practice after which the treatment has been realised and is outside the control of the designer of the treatment. Implementation can be followed by an evaluation of experience, which may lead to a new iteration through the cycle.

### 3.2 Principles of Artefact Orientation

In artefact-based RE improvement, we focus on a specialisation of the previously introduced engineering cycle where the treatments focus on artefacts and artefact models. As artefact orientation comes with a plethora of interpretations, we rely on a meta model we developed for artefact-based RE [12]. This meta model defines the constructs and rules for artefact-based RE, i.e. the basic notion of artefacts and how they relate to further process elements like roles.

We define an *artefact* as any document or data set required by an RE process in its intermediate or final form, e.g. models and specification documents. Each artefact has structure, usually captured in a taxonomy (comparable to a document outline), a particular content that defines a blueprint of the modelling concepts, and it is formulated in some syntax agreed by stakeholders. During artefact-based RE improvement, our process-agnostic focus on artefacts allows us to abstract from the variability in the processes, because the actual creation of artefacts by the use of particular methods in a particular sequence is reduced to the created artefacts, their contents, and their dependencies. During analysis, the focus on what has been produced rather than on how it has been produced results in an empirical understanding about how RE specifications are created and used in practice, and in a proposal to improve RE in a problem-specific way. The subsequent problem-driven implementation of an *artefact-based RE reference model*, i.e. the RE reference model including the artefacts, their structures, and their dependencies, as well as roles and responsibilities, supports the project-specific flexible creation of consistent result structures in contrast to when concentrating on methods and dependencies [12,13].

### 3.3 Artefact-Based RE Improvement Approach

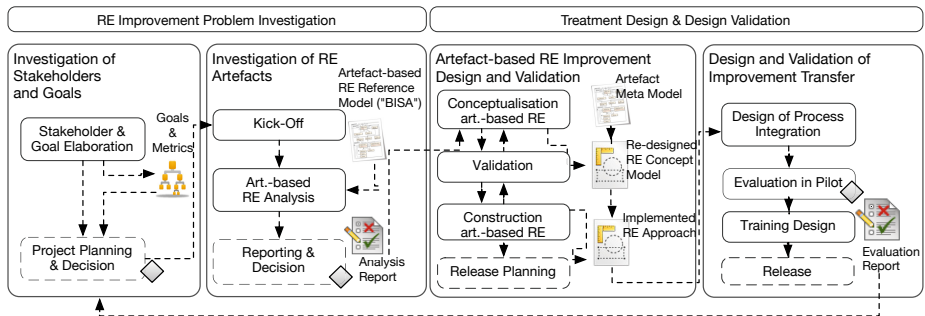
Our artefact-based requirements engineering improvement approach emerges from experiences we gathered in a series of research projects with German companies. Table 1 summarises an excerpt of completed projects where we followed

the principles of design science introduced in the foregoing section and where we applied the same empirical methods to conduct an artefact-based RE improvement. Details on the empirical methods applied during problem investigation and design validation in those projects can be taken from [5].

**Table 1.** Research projects that served as basis for the RE improvement approach

Project	Company	Objective	Results
A	Capgemini TS (Germany)	Exploratory study on organisational and project-specific needs and RE improvement leading to the company standard for RE.	Study: [6], on demand
B	Siemens	Feasibility study on application of requirements engineering approach to qualitatively compare legacy approach with new approach	Study: [13]
C	Deutsche Lufthansa	Study to analyse requirements engineering process definition and exemplary development project	Confidential

The resulting overall artefact-based RE improvement approach is illustrated in Fig. 3 and incorporates the commonalities and experiences of all previously conducted action research projects.



**Fig. 3.** One iteration through the artefact-based RE improvement life cycle

The approach contains a set of tasks of the engineering cycle (marked with solid shapes) and a set of management tasks (marked with dashed shapes). Milestones indicate decision points about the initiation of the next phase. In the following, we introduce each phase in detail.

**Investigation of Stakeholders and Goals.** In the first phase, we identify the stakeholders and their RE goals, and potential measurements to evaluate whether the improvement (given treatments) has achieved those goals at the end of an iteration. We then decide together with the stakeholders on whether to initiate an artefact-based improvement at all in dependency to the stated goals and available experiences about how well artefact orientation is generally suited to satisfy those goals. Those experiences arise from experimental research where

we investigated to which extent particular goals such as “increase the syntactic consistency in the RE artefacts and support traceability” are supported by artefact orientation. An exemplary study that indicates to different goals supported by artefact orientation is provided in [13]. We create a project plan that includes which cases and subjects are necessary and when they will be involved, e.g. as part of workshop sessions or interviews. The plan is then put into a schedule with an appointment for a kick-off workshop clarifying also contractual issues like confidentiality (see, e.g. [14]).

**Investigation of RE Artefacts.** The investigation of RE artefacts considers the analysis which phenomena can be observed when applying the company-specific RE reference model in projects and what effects the application has. The analysis serves the identification of relevant RE artefacts and potential shortcomings. To conduct this analysis in an artefact-based manner, we define three research questions:

**RQ1** Which artefacts are created in which syntactic quality?

**RQ2** What is the artefacts’ semantic quality?

**RQ3** What is the quality of RE from the perspective of project participants?

The data collection procedure begins with a preparation phase in which we collect information about the definition of the RE process (i.e. artefacts, processes, milestones, and roles and responsibilities) and conduct one knowledge transfer workshop on artefact orientation. This supports us in creating a big picture of the overall RE process, its dependencies to surrounding processes, as well as the definition of the scope for the analysis. The subsequent data collection and analysis procedure then concentrates on manual and tool-supported document analyses and interviews; both serve the purpose of identifying an RE artefact model as it is lived in current company practice and which stakeholder-appropriate measures can be taken to improve that model. The results are then documented in a report, which we structure following the guideline proposed by Runeson et al. [14] and which we discuss in a concluding joint workshop. We identify following techniques to be useful to conduct the analysis procedures for answering our research questions.

*Syntactic Document Analysis (RQ 1).* We analyse provided documents from a series of representative company-specific development projects in which the current RE reference model is applied. The comparison with the company-wide process definition serves to harmonise potential terminological deviations in the projects. During a document analysis, we induce an (“as-is”) artefact model from the project documentation. To this end, we define a structure model that defines which general content items are created in the projects. In an in-depth analysis, we enrich this structure model with a content model that abstracts from the modelling concepts used in the projects to create the requirements specifications; for instance, we define which elements and relations are used to create the use case models and how they relate to other concepts such as the ones of acceptance testing. In a second step, we perform a gap analysis and compare the created artefact model to an artefact-based RE reference model we have developed over the last years based on current best practices and the state of



the art, namely the BISA model (“Business Information Systems Analysis”) [15], see also Fig. 3. We use deviations from the current artefact model to the BISA model to discover (1) potential fields of improvement, which we (2) validate in the interviews (RQ 3) to ensure the problem-driven nature of our analysis.

*Semantic Document Analysis (RQ 2).* For each class of requirements defined in the project-specific specifications, we take random samples and manually analyse them for semantic inconsistencies, ambiguities, linguistic defects (amortisations or generalisations), and redundancies; for instance, we identify inconsistencies by conducting a walkthrough through the documents following the references provided in the corresponding specification sections. The semantic document analysis serves in addition to the syntactic analysis to identify which modelling techniques and textual artefact templates could help to avoid potential problems.

*Qualitative Analysis of Expert Interviews (RQ 3).* Having investigated the documents in isolation, we conduct interviews with representatives from the corresponding projects. Those interviews aim at encouraging the participants to reflect on their current practice and help us to get a better understanding of the project backgrounds. To this end, we define open and closed questions and ask for potential improvement fields in the company-wide RE reference model and for decisions taken in the projects that have led to the analysed documents. The latter is structured according to the content items in the artefact model, which took our attention during the syntactic document analysis. We ask, for example, for artefacts being incomplete or missing in comparison to the BISA model and why they have been specified in this particular way. This helps us to validate the current practice and to understand contemporary needs in the project environments, as well as to adopt the treatment to the organisational context; for instance, by defining under which circumstances to create specific RE contents recommended in practice, i.e. to prepare tailoring profiles for the new improved RE reference model.

**Artefact-Based RE Improvement Design and Validation.** The actual RE improvement considers the practical problem solving in design science and is conducted over three engineering steps performed in iterations. We begin the conceptualisation of the new (“to-be”) artefact-based RE reference model by conducting a series of action research workshops. In those workshops, we begin with a simplified view on an artefact model and sketch their currently used artefact model using whiteboards and paper cards. We begin the design of the artefact model on basis of the artefact model created during the analysis with RQ 1 and validated with RQ 3, i.e. we use the artefact model abstracting from their project documentation and extend it step-by-step with those content items proposed by the BISA and found useful by the stakeholders to support for their goals. Where reasonable, we annotate project-specific situations in which to omit the creation of the content items to infer, in the end, a tailoring profile. We enrich the artefact model with milestones, roles and to which further development artefacts the content items relate (e.g. acceptance testing) for the subsequent process integration. Between those workshops, we build the improved RE

reference model by conceptualising the artefacts, roles, and milestones in isolation without direct stakeholder involvement with, e.g. UML class diagrams, before discussing resulting concepts again in joint workshops. After validating the proposed concepts and their effects on the organisational context and whether the concepts help to overcome the shortcomings identified in the analysed projects, we implement the concepts in a tool-supported manner, which itself is considered as a technical validation [16]. This implementation considers, for example, the design of UML profiles and their implementation as part of CASE tool plugins.

**Design and Validation of Improvement Transfer.** Once the RE reference model is conceptualised and constructed, it is disseminated. This dissemination itself must be designed. This includes the design of the process integration, i.e. the integration of the RE reference model into existing organisational practice by defining the dependencies between the elements in the new approach and elements in the overall development process model (e.g. the dependencies between the new RE artefacts and further existing architectural design or testing artefacts). After evaluating the new approach in a pilot project, we need to carefully design its training and release. The evaluation itself needs to investigate whether we eventually improved RE in dependency to the initially stated goals and the problems discovered during the analysis. To this end, we apply the new RE reference model in a pilot project and compare the conducted RE process as well as the created artefacts with the previously used approaches using interviews, both used to evaluate potential improvements of the variables investigated with the previously stated research questions. An exemplary evaluation investigating the improvement of the syntactic and semantic quality of the RE artefacts and of the flexibility in the RE process is shown in [13]. If the improvement is accepted, we design training material and release the model, before initiating, where reasonable, the improvement life cycle again. At the example of project A in Tab. 1, we conducted three iterations over 2 years, before the resulting artefact-based RE reference model was declared as the company standard.

## 4 Preliminary Results from Ongoing Evaluation

The introduced approach has been developed based on experiences we gained in fundamental and applied research projects in the area of artefact orientation [12] and the application of developed concepts in different research projects to solve industrially relevant problems (see Tab. 1). So far, the resulting problem-driven approach is successful, because up to now the concepts of artefact-based RE improvement have resulted in an successful RE improvement leading, e.g. to new company-specific RE standards (see, e.g. project A). We have, however, reached the point where we need to empirically evaluate our approach in different socio-economic contexts. Also, it yet has to be shown whether our approach can be used by others if we are not involved at all.

Our current evaluation, described next, is one step in this direction. Currently, we are conducting two research projects, each of them with a duration of one year. One project is performed with Wacker Chemie (Munich, Germany). The

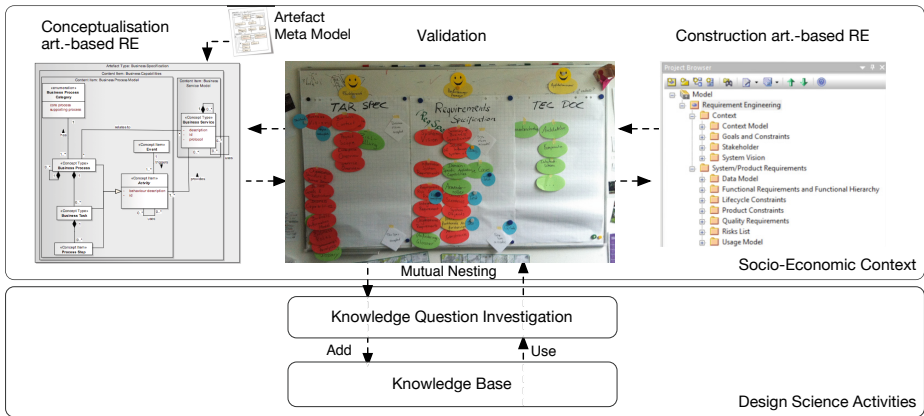
company works in the chemical business and develops, inter alia, custom software for their operation processes and their production sites. We are applying our approach to improve their RE reference model. At the time of writing the paper, we finalised the improvement design and validation phase and are currently evaluating the resulting artefact-based RE reference model of the company in a series of pilot projects (Fig. 3, phase 4). In the following, we first discuss lessons learnt gathered from applying our approach, before summarising the results from an intermediate evaluation we performed with the involved process engineers.

**Lessons Learnt.** The most remarkable observation we have done so far considers the artefact-based RE improvement design and validation phase. We observed that we are shifting the approach from a classical action research paradigm to a *canonical action research* paradigm [17]. This means that we, as researchers, are not taking the exclusive role anymore, in which we do process consultation by proposing different solutions, which are then discussed with all technical details in workshops. Instead, the approach is now strongly iterative and collaborative in which the researchers take a more observational perspective.

We have used this observational role for two purposes: The first purpose is to generate new knowledge, i.e. to draw further conclusions about artefact orientation itself and how it manifests in practical settings as the paradigm still comes with various practical interpretations and implications [12]. We consider this also to be the main reason for the shift to a canonical action research. The second purpose is to guide the solution finding process between the stakeholders rather than proposing different solutions and risking to miss company-specific (hidden) requirements. To this end, we begin with the results of the analysis and encourage them to design their new artefact-based RE model on their own on a white board while we actively aim at knowledge transfer regarding possible implications of their design decisions. Figure 4 briefly sketches the role of the workshops.

In the centre of the figure, we illustrate the whiteboard and the paper cards used at Wacker as a means for the improvement design and validation workshops. Each card symbolises a content item identified during the investigation of RE artefacts. The structuring and colour coding of the cards results from the gap analysis: red cards (left part of the photo) illustrate content items that were missing in comparison to the BISA model, yellow cards illustrate incomplete content items, and green cards (right part of the photo) illustrate content items that were specified in full. During the improvement workshops, we further abstract from technical details of artefact orientation to not interrupt discussions between the stakeholders, i.e. instead of focussing on models and their technical details, we focus on paper cards and keep technicalities away from the discussions. We still continuously ensure the conformance of the new model sketched during the workshops to the underlying meta models (see Sect. 3.2) to ensure the feasibility during implementation.

Although we have experienced a generally high effort for the RE improvement, we believe this procedure to be the more effective one, because we expect it to pay off in reduced rework later. We have already observed a high communication between the stakeholder focus groups while backing their decisions in their



**Fig. 4.** Continuous knowledge transfer during validation workshops while abstracting from realisation details (re-design concept model, meta models, and construction)

project environments. Over and above all, we believe that this procedure best reveals the problem-driven nature of our approach. These observations, however, need a deeper empirical evaluation, which we are currently performing.

**Intermediate Evaluation.** Currently, we are performing an empirical evaluation of our artefact-based improvement approach where we evaluate it in comparison to previously used process-oriented and solution-driven approaches taking into account resulting RE reference models, i.e. we evaluate our improvement approach and its results. This evaluation considers the overall artefact-based RE improvement undertaking at Wacker Chemie involving 4 researchers and 5 process engineers of the company with an estimated effort of 8 person months including in total 13 workshops (each with a duration of 4 hours).

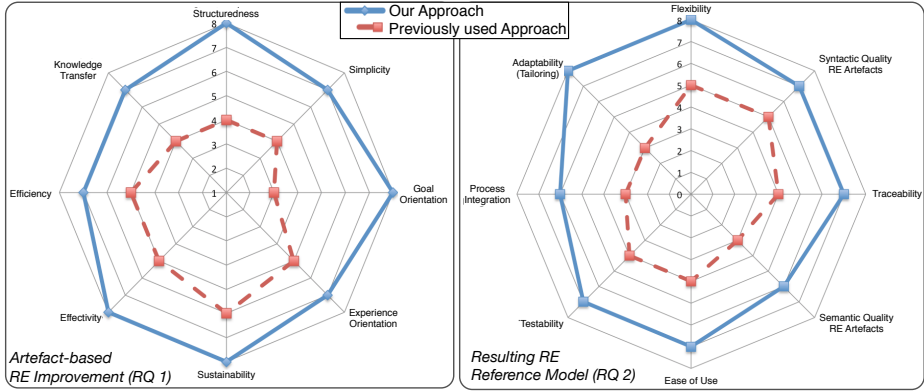
In the following, we briefly summarise the results from an intermediate evaluation we performed with the process engineering group involved in the workshops and remaining anonymous. The initial evaluation serves to detect first trends and validate the study design itself. Since this is a preliminary evaluation, we do not go into details and refrain from a rigorous study design and interpretations of the results. The evaluation will be completed after finishing the research project to allow for more precise and generalisable results taking also into account the expert opinion of project participants that apply the resulting artefact-based RE reference model. The overall evaluation is steered by two research questions:

**RQ1** How well are process engineers supported in their RE improvement tasks?

**RQ2** How well are project participants supported by the RE reference model?

The first question directly evaluates our improvement approach for applicability and usability, and the second question evaluates the appropriateness of the resulting RE reference model from the perspective of project participants. During the intermediate evaluation, we conduct an assessment where the lead of the process engineering group answers a questionnaire (jointly discussed with the group). The questionnaire includes 8 criteria for assessing the improvement approach and 8 criteria for assessing the resulting RE reference model. For each

criterion, we define a closed question where we ask for the agreement to a given statement distributed over a Likert-scale from 1 = *I strongly disagree* to 8 = *I strongly agree*, and we ask in an open question for their expert opinion and the rationale of the rating to support a reproducible result. Figure 5 summarises the results from the evaluation.



**Fig. 5.** Results from an intermediate comparative evaluation of the improvement approach (left side) and of the resulting RE reference model (right side)

In general, our improvement approach was overly rated to be better suited for a problem-driven RE improvement in comparison to previously used process-oriented and solution-driven RE improvement approaches. The overall rating already indicates to confirm our perceived support for the aforementioned problem-orientation and, in particular, to support for knowledge transfer. Our approach is stated to be problem-driven whereas previously experienced undertakings “disregard [company-specific] main objectives [...]” and the “[...] integration of quality management aspects into RE [...]”, which was a major improvement goal. In contrast to our observation of the lower efficiency due to our effort spent in the preparation of the workshops, the workshops were perceived as efficient. Previous undertakings were rated to be “less efficient [having a] longer time period for the conception phase with more workshops needed”. Similarly, the structuredness was rated high due to the “logical and continuous approach”. The simplicity was rated to be high in comparison to previously used approaches, because those were focussing on “method-based approaches, which imply process models [leading to] more complexity both the projects and for quality management”. Finally, the effectivity was rated to be high due to the “conception of content items structures, their relationships and dependencies, and an overall traceability”, i.e. the artefact-based nature of the new RE reference model.

The resulting artefact-based RE reference model (RQ 2) is thus perceived to be an improvement in comparison to the previously used RE reference model. In particular, the flexibility and the adaptability is rated to be of high quality due to the artefact-based nature and the inferred tailoring profiles. The artefact-based

nature also indicates to reveal the benefits in supporting a higher quality in the RE artefacts when applying the model in project settings. This is reflected in the rating of the syntactic quality of the artefacts w.r.t. consistency and completeness and in the aforementioned traceability. As we profoundly took into account the interfaces of the artefacts to further development tasks, the reference model is rated to be well integrated into the overall software development process.

These preliminary results suggest that our artefact-based RE improvement approach is well suited for a problem-driven improvement, but cannot be taken as definitive in any sense. The evaluation needs deeper examination and the participation of all project participants of the currently ongoing pilot phase. This should reveal more insights into benefits and any negative, unforeseen phenomena that would motivate further development of our RE improvement approach.

## 5 Conclusion

In this paper, we contributed a problem-driven, artefact-based RE improvement approach and made explicit the steps we successfully applied in different research co-operations where we developed artefact-based RE reference models for companies in a problem-driven manner over the last 5 years. We introduced the basic concepts of our artefact-based RE improvement approach and discussed preliminary experiences from an ongoing evaluation, which needs, however, deeper examination as well as replications to increase the validity of our results.

Our problem-driven improvement approach already seems to avoid the pitfalls of solution-driven process improvement approaches, in which ways of working alien to an organisation, and not relevant for its problems, may be introduced. The artefact-based nature of our approach increases the freedom for process improvement as the focus lies on the RE artefacts rather than on strict, inflexible processes used to create and modify the artefacts. The artefact models abstract from processes, methods, and description techniques. This supports a structured analysis and improvement of RE in joint action research workshops with stakeholder focus groups without having to take into account the inherent complexity of the RE processes in their individual project environments.

We thus made first steps in closing a gap in current improvement research that is often solution-driven and process-oriented, focussing on assessments of processes of a company against a pre-defined solution that is propagated to be per se of high quality. We do not claim that our approach suits every situation in which to improve an RE process of a company. In fact, we discussed that we need further understanding about the general benefits and limitations of artefact orientation by relating it to business domain characteristics. Furthermore, the success of every improvement endeavour in a socio-economic context depends on many soft factors that hardly can be formalised in a procedure. Consequently, we encourage researchers and practitioners to critically discuss our approach and to join us to empirically evaluate artefact-based RE improvement.

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