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Tool support for disseminating and improving development practices

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Abstract Knowledge management in software engineering and software process improvement activities pose challenges as initiatives are deployed. Most existing approaches are either too expensive to deploy or do not take an organization's specific needs into consideration. There is thus a need for scalable improvement approaches that leverage knowledge already residing in the organizations. This paper presents tool support for an Experience Factory approach for disseminating and improving practices used in an organization. Experiences from using practices in development projects are captured in postmortems and provide iteratively improved decision support for identifying what practices work well and what needs improvement. An initial evaluation of using the tool for organizational improvement has been performed utilizing both academia and industry. The results from the evaluation indicate that organizational characteristics influence how practices and experiences can be used. Experiences collected in postmortems are estimated to have little effect on improvements to practices used throughout the organization. However, in organizations where different practices are used in different parts of the organization, making practices available together with experiences from use, as well as having context information, can influence decisions on what practices to use in projects.

Keywords Postmortem review · Knowledge management · Software process improvement · Software · Engineering

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1 Introduction

Software organizations must continually strive to maximize the utilization of the knowledge and experience internal to the organization for refining and improving their development practices. Development practices are ultimately based on the knowledge and experiences of the organization's staff. The challenge for leveraging experiences regarding practices is that they are often localized to the individual or project in which they are gained. The challenge is amplified by trends to distribute software organizations and development (Jaakkola et al. 2010) as experiences are more likely to be shared within groups of people that interact with each other. To overcome this challenge, knowledge management in software engineering has focused on documentation and use of experiences to generalize and distill best practices (Basili et al. 2001, 2002a, 2002b; Rus et al. 2002; Schneider and Schwinn 2001). A potential problem with this formalization and generalization is a reduction in local practices needed to cope with uncertainty and local problems (Swan et al. 1999).

Performing postmortems upon project conclusion is closely related to learning from project experiences and supporting organizational knowledge by making experiences explicit (Glass 2001; Nolan 1999; Verner and Evanco 2005). Postmortems can have a learning effect on an individual level, team level and organizational level (Desouza et al. 2005). However, few studies have focused on the organizational level (Dingsøyr and Conradi 2002). Even if experiences are captured and stored, they are not always reusable or even usable by their intended audience (McDermott 1999). This becomes evident when looking at state-of-practice reports of software engineers not learning from past mistakes (Birk et al. 2002; Broessler 1999) and experiences owned by the organization being overlooked (Broessler 1999).

This paper introduces tool support for utilizing postmortems in an Experience Factory approach (Basili et al. 2002a) for improving and diffusing practices in an organization. Practices in this context include any method, technique, procedure, tool, or model used for software development. Postmortem reviews are used to evaluate the development practices used, and the results from the evaluation are stored as experiences in the tool, which makes them available for other parts of the organization. Other projects can use the tool to find out what practices are used in the organization and how they have performed in other projects. This can be used as input to deciding what practices to use in projects, and thus as an aid in diffusing practices that have worked well and also in transferring knowledge embedded in the practices. The process improvement organization can use the evaluations to find areas in which practices need improvement.

This paper presents an initial evaluation of the tool in academia and at three different companies, all with different characteristics. Participants in the evaluation use the tool in a number of scenarios related to practice improvement and diffusion, and rate how it would change the current situation. The results indicate that in organizations where practice documentation reflects actual practice and projects are in a position to learn from each other, diffusion of practices can take place. However, using postmortem data to affect organization-wide practices is not seen as likely. In addition, the results highlight the need for trust and resources for enabling learning from experience. Trust relates to how different parts of the organization value experiences of others. If there is little trust in others' experiences, learning will not happen. In addition, without dedicated resources for change available, even the best effort for identifying what needs to change will not lead to realization.

The paper is structured as follows. Section 2 provides an overview of research on the Experience Factory and postmortems and discusses their characteristics and possible limitations. In Sect. 3, an overview of the Practice Selection Framework (PSF) and associated tool support is introduced. Section 4 presents the design of the evaluation, including research questions to be answered. The results from the evaluation are given in Sect. 5. Finally, conclusions are presented in Sect. 6.

2 Background and related work

There are many methods and frameworks that take organizational learning into account. Knowledge management in general, but also in relation to software engineering in particular, has discussed the importance of managing and utilizing knowledge and of spreading tacit and explicit knowledge in an organization (Aaen 2003; Rus and Lindvall 2002). The recognition that practitioners themselves are the main company assets makes this even more evident. In software engineering, the Experience Factory (EF) (Basili and Green 1994; Basili et al. 2002a) has been central for reusing life cycle experiences and products for software development. Experiences are collected from development projects and are packaged and stored in an experience base. Packaging entails generalizing, formalizing, and tailoring the information collected to be easy to reuse. The idea is that software development projects can improve their performance through the utilization of experiences from previous projects. The classical usage of EF utilizes the Quality Improvement Paradigm (QIP) (Basili and Green 1994) for software process improvement (SPI) supported by the Goal Question Metric (GQM) (Basili and Green 1994) for establishing project and corporate measurements. The instantiation of EF requires the creation of a new Experience Factory organization to be responsible for the analysis and packaging of the experience collected. Packaging is a difficult task in itself (Schneider et al. 2002), and the cost of the EF organization is about 10% of the total organizational project budget (Basili et al. 2002b). This is not to say that EF has negative return on investment, but rather that the commitment and thus the initiation threshold for such an undertaking are considerable. The most prominent use of EF as described above is the NASA SEL (Basili et al. 2002b) (for a review of research on EF, see Dingsøyr 2000). However, even though the EF at NASA may have had a positive return on investment, few organizations have the resources to implement and run a similar effort. To overcome this problem, the Knowledge Dust to Pearls approach (Basili et al. 2001; Rus et al. 2002; Lindvall and Rus 2003; Lindvall et al. 2001) capitalizes on both analyzed (Pearls) and unanalyzed experiences (Dust). Unanalyzed experiences satisfy the short-term needs for experience sharing and are later analyzed and packaged into best practices.

The challenges with managing experiences point toward the difficulty of evaluating tacit knowledge and deciding what knowledge should be made explicit. The costs are high for making knowledge explicit and for using training as one major vessel of knowledge transfer, and accuracy can be hard to gauge, i.e., what knowledge should be made explicit, packaged and transferred? The actual transference is also a challenge. For a project manager initiating a project, the choice of what practices to use is many times based on a "gut feeling" derived from experience and tacit knowledge (Rus and Lindvall 2002). Using, e.g., predictive or process models that require large amounts of project data as input, or using simulation, can support practitioners (Abdel-Hamid and Madnick 1991), but transparency and, ultimately, trust can be an issue. In addition, the cost of keeping high-quality/high-accuracy data for every project up-to-date, making it suitable for input to the

prediction simulation, again becomes a problem, as high initiation and maintenance costs increase the initiation threshold of any process improvement activity (Calvo-Manzano Villalón et al. 2002; Kuilboer and Ashrafi 2000; Reifer 2000).

The concept of performing postmortems upon development project conclusion is closely related to the concept of supporting organizational learning and making experiences explicit, and can be seen as vital for process improvement activities (Glass 2001; Nolan 1999; Verner and Evanco 2005). Performing postmortems is both practical and low cost, offering clear benefits, while it also has a low initiation threshold, i.e., is suitable for organizations of all sizes. The main problem is that organizations seldom perform postmortems, even if they are in the official process charter, as pressures to start the next project overshadow the good intentions of learning. Verner and Evanco report that, of 42 projects studied, only 33% had postmortem reviews (Verner and Evanco 2005), even though performing postmortems was associated with the production of high-quality development artifacts and the ability to manage risk more efficiently throughout the development process (Verner and Evanco 2005). As a result, the same mistakes propagated across projects over time.

Another problem is that, even if postmortems are performed, information is seldom shared across project boundaries (Birk et al. 2002; Glass 2002a; von Zedtwitz 2002), with the result that the only vessel for knowledge transfer is the individual practitioner moving between projects. Methods for analyzing postmortem data for use on an organizational level exist, but carry high costs (Dingsøyr et al. 2007; Schalken et al. 2006). The project managers, who are the driving force behind selecting the practices to be used in a specific project, might or might not be involved in the learning experience of another project. This problem is compounded by the fact that few organizations have procedures or structures in place to enable sharing of information (Glass 2001; Verner and Evanco 2005; von Zedtwitz 2002). This can be devastating, as good practices are highly dependent on project characteristics, i.e., what works for one project might not be suitable for another (Davis and Zowghi 2004; Glass 2002b). Relying only on word-of-mouth rumors, good practices conveyed out of context with little or no additional information can create more problems than they solve.

Tools for experience storage and retrieval in software engineering have been developed, and experiences from using these have been published. Related to this paper, experiences have been connected to electronic process guides (EPGs) (Scott and Jeffery 2003; Kurniawati and Jeffery 2006; Scott and Stålhane 2003; Bjørnson and Stålhane 2005). The type of information kept is mostly development artifacts such as project documentation, templates, and checklists. The advantage of using development artifacts already present is that it offers a low-cost way of collecting experiences that are readily available for ad hoc reuse. The Visual Query Interface (VQI) (Lindvall et al. 2001) also provides structure and tools for organizing and searching for experiences. Experiences from using VQI have also mostly focused on reusing development artifacts (Lindvall et al. 2001). Both VQI and Well of Experience (WoX) have been used for supporting developers in their tasks, e.g., by documenting solutions to recurrent problems (Lindvall et al. 2001; Dingsøyr and Conradi 2003). Other tools such as Skill Manager (Dingsøyr and Conradi 2003) have been used for keeping track of competence and experienced staff in the organizations.

3 Practice selection framework

The tool support presented in this paper implements the Practice Selection Framework, which is a tailored Experience Factory approach in which postmortems are used to evaluate

practices used in development projects. This section introduces PSF and the tool developed to evaluate PSF. The main motivation for using postmortems to capture experiences is that few organizations have precise quantitative measurement programs to discern practice performance. In addition, the dedicated resources needed for running an Experience Factory are large (Basili et al. 2002b). Lowering the resource demand could enable more organizations to capitalize on experiences and knowledge inherent to the organization, for improvement. Using practices already available in the organization to transfer knowledge between projects limits the initiation threshold. Practices used in the organization can be stored in PSF, immediately making them available throughout the organization. Experiences collected then provide iteratively improved decision support for deciding what practices to use.

PSF (illustrated in Fig. 1) is meant to provide decision support to utilize experiences captured in postmortems to enable organizational improvement. This is achieved using part of the postmortem to evaluate the practices used in the development project and store these experiences in PSF to provide decision support for project and process managers.

Improvement often involves introducing a new method, tool, technique etc. Thus, practices are a good candidate for conveying experiences. The use of PSF depends on organizational characteristics. If the organization prescribes what practices to use in projects, PSF can be used to provide feedback on organizational practices and bridge a potential gap between project and line organization (process improvement organization). Feedback of experiences can be used by project managers to improve current development practices. In addition, evaluations of prescribed practices can identify where variations in used practices are needed, i.e., circumstances when prescribed ones do not perform well. If projects in the organization are free to select what practices to use, PSF can be used to aid diffusion of practices that have worked well to other projects. Projects are given access to all practices used in the organization and how these have performed in previous projects, and can use this as input when deciding what practices to use in their project. In comparison with EF, the goal of PSF is not necessarily to generalize practices, but rather to promote using local practices to cope with local problems (Lyytinen and Robey 1999).

PSF collects experiences from several development projects, enabling prioritizing improvement needs on the organizational level, i.e., identifying what is most important to improve first, given the organization's goals instead of individual projects' goals (Lyytinen

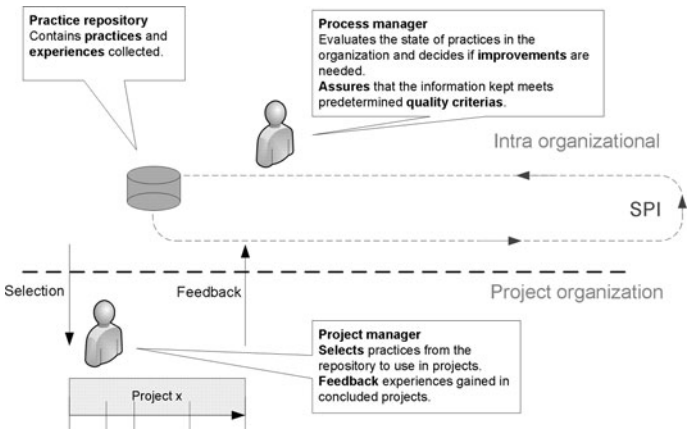

Fig. 1 Practice Selection Framework

and Robey 1999). Improvement in projects often happens as a reaction to a problem, and might thus address issues not beneficial to the organization. For example, extensively adding features to an architecture in one project might render it hard to use in other projects.

PSF is meant to relate to state-of-practice for documenting practices in the organization, and not to introduce new requirements for practice descriptions. Experiences are then related to existing practices by traceability. PSF is described in more detail in the next Section, where prototype tool support is introduced.

3.1 Tool support

To evaluate using postmortems to capture experiences as in PSF, prototype tool support has been developed. The purpose of the tool is to collect feedback on PSF and to identify functionality needed to use PSF efficiently.

The data model used in PSF is the same as in EF (Basili et al. 2002a) (illustrated in Fig. 2). Experiences are traced to both the project in which they were captured and the practice they concern. Keeping traceability to the context in which the experiences have been captured enables evaluation of how practice performance is affected by context and also enables users to evaluate if an experience is valid in their own context.

To structure and ensure a minimum level of data collected, documentation of practices, experiences, and project is attribute-driven. The attributes for each entity should be tailored to fit the needs of the organization. Collecting subjective data places high importance on the definition of the attributes and on seeing that all users feeding back and using the information have the same understanding of the attributes. Some of the attributes used to capture experiences during the evaluation presented in this paper are given in Fig. 3. Experiences are traced to both projects and practices. In addition, traceability to the persons responsible for using the practice in the project is kept. This enables users of PSF to locate knowledgeable people in the organization from whom they can get additional information about the experience and the practice.

To distinguish how practices have performed in projects and thus identify practices that have worked well or warrant improvement, practice performance is evaluated from different perspectives. Examples of attributes used to document practice performance in the evaluation are given in Fig. 3. Effectiveness concerns the degree to which the practice achieves its purpose. For example, for a review practice, effectiveness concerns the share of defects found in the artifact reviewed, and efficiency concerns the rate at which defects

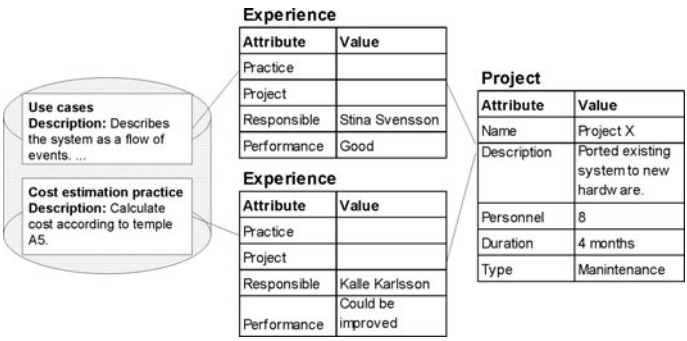

Fig. 2 Data model in PSF

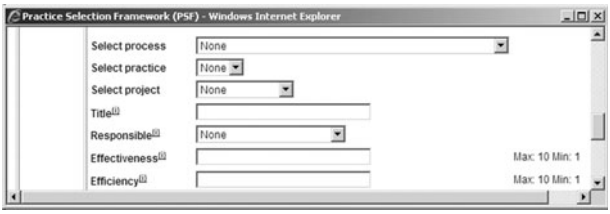

Fig. 3 Feedback of experiences

Fig. 4 Process view

are found, i.e., defects per hour. Evaluating these perspectives with expert opinion means that the precision in the estimate is rather low. To improve this, objective measurements should be used as input to the estimation if available. However, the important precision to have is whether the practice has performed well or not. This enables identifying good practices and those needing improvement. Deciding on what practices to use in a project is a complex task that needs to consider project and product factors, knowledge of staff etc. PSF is meant to provide additional input to this decision process by providing alternatives that are already used in the organization.

The tool currently implements two ways of finding relevant practices and experiences, through a process view and a project view (Schneider and Schwinn 2001; Scott and Jeffery 2003). The process view is shown in Fig. 4. The idea is to have practices connected to the process so that users can locate what practices the organization has experiences from using for specific parts of the process. In the evaluation, the process from CMMI (CMMI Product Team 2002) is used. If used in an organization, the process view should ideally be the process that is used in the organization.

The users can select any part of the process to get an overview of all practices available for it. For instance, selecting the process "Elicit needs" gives all practices used in the organization to elicit needs. For each process, a ranking of practices is given, regarding how projects have evaluated them. This provides users with an overview of what practices have been estimated to perform best and worst for each performance attribute of the process. In addition, each practice is presented with a summary of the performance attributes collected for it, as shown in Fig. 5.

To get a better understanding of how relevant the experience is and in what projects the practice has been used, users can access all experiences collected for the specific practice. An example of an experience used in the evaluation is given in Fig. 6. For each experience, a short description of the project in which it has been captured is given. The full description of the project can also be accessed if needed.

Fig. 5 Practice description

Practice	Reuse requirements (click title for more information)
Project summary	
Title	Project Alpha (click title for more information)
Project type	PC system, PC back end
Description	Changed technical platform for a customer management system. The system PC based (Windows Server), Oracle DB, and thin clients.
Man hours	154100
Level of change	3
Experience	
Title	Reused a large part of the requirements from the last version of the system
Responsible	Kalle Karlsson (karlK)
Effectiveness	★★★★★★★★★☆
Efficiency	★★★★★☆☆☆☆☆
Cost effectiveness	★★★★★☆☆☆☆☆
Quality	★★★★★★★★★☆
Usage time	200
Pros	
Cons	
Comment	The reused requirements were of high quality and saved time later in the project.
Recommendations	Plan for reuse of requirements. A lot of time can be saved if

Fig. 6 Experience description

The other way to access experiences is to access specific projects carried out in the organization and view experiences collected from each. This can be used to identify good and bad experiences from projects similar to the present one.

4 Research methodology

The Practice Selection Framework has been developed in several steps. After the first concept was developed, it was tailored and evaluated in a workshop in industry. The results

from the evaluation were generally positive, and improvement proposals from the workshop were used to refine the concept. To improve understanding of using postmortems for organizational improvement, tool support for PSF was developed to enable further evaluation. Two different evaluations are presented in this paper—first an evaluation in academia and then one in industry. The research questions addressed in the evaluation are given in Sect. 4.1, and the design of the study is given in Sect. 4.2.

4.1 Research questions

This Section presents the research questions that the evaluation addresses. Each research question is given in Table 1 with a description/motivation.

4.2 Study design

The steps in designing the evaluations are given in Fig. 7. First, the evaluation is planned, i.e., how to perform the evaluation. Planning for the evaluation is presented in Sect. 4.2.1. The evaluation aims to collect feedback on PSF usage. To enable usage, tool support was developed to enable potential users to use PSF prior to implementing it. Tool support is presented in Sect. 3.1. The material used in evaluating the tool is presented in Sect. 4.2.2. The evaluation is first performed in academia to initially evaluate PSF and refine the tool prior to commencing industry evaluations. Starting with an evaluation in academia is a low-cost way to test and improve PSF before starting evaluations in industry. In addition, the academic evaluation doubles as a test of the evaluation material and the PSF tool prior to industry evaluation. The results from the academic evaluation are presented in Sect. 5.1.

Table 1 Research questions

Id	Research question	Motivation/description
RQ 1)	Is PSF usable?	This research question concerns the usability of PSF and the PSF tool. If PSF is not usable, there is a significant risk of abandoning the approach
RQ 2)	Is PSF useful for improving practices related to diffusing good practices and identifying improvements?	For PSF to be useful for making decisions regarding adopting and improving practices used in the organization, the benefits of using the approach need to outweigh the cost of using it. This research question thus essentially concerns the usefulness of using PSF
RQ 2.1)	Is PSF useful for identifying practices for adoption?	For experiences to be useful as decision support for adopting practices, the costs of collecting and analyzing them need to be lower than the expected benefits
RQ 2.2)	Is PSF useful for identifying improvement potential?	For experiences to be useful as decision support for identifying improvements, the costs of collecting and analyzing them need to be lower than the expected benefits
RQ 2.3)	Is PSF useful for identifying practices that have been used in similar projects?	For PSF to be useful to find practices used in similar projects, the costs of collecting and analyzing experiences need to be lower than the expected benefits
RQ 2.4)	Is PSF useful for finding knowledgeable persons in an organization?	For PSF to be useful to identify knowledgeable persons, the costs of keeping track of experiences need to be lower than the expected benefits
RQ 3)	What are the challenges to using PSF?	To understand the risks involved with implementing PSF, challenges to PSF usage need to be understood

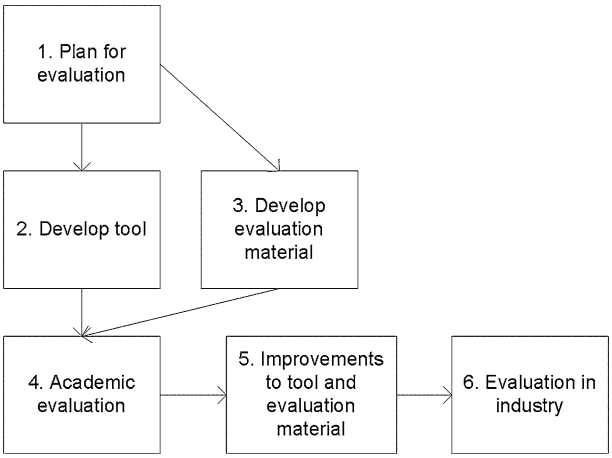

Fig. 7 Study design

The evaluation performed in industry is presented in Sects. 5.2 and 5.3. Section 4.2.3 provides details on the operation of the evaluation. Finally, threats to the validity of the study are discussed in Sect. 4.2.4.

4.2.1 Plan for evaluation

The study presented in this paper intends to collect initial feedback on using postmortems for organizational improvement. The evaluation involves letting participants use the PSF tool in order to be introduced to using postmortem data for diffusing and improving practices used in the organization. The specific tasks performed by the participants as part of the evaluation are:

- Find useful practices to use for a specific task.
- Find practices used in specific projects.
- Find practices with improvement potential.
- Find knowledgeable persons in the organization.

The tool is filled with examples of practices, projects, and experiences prior to the evaluation, of which some are presented in Sect. 3.1. All examples are from requirements engineering (RE) practices. After having completed the tasks, a questionnaire aimed at collecting the participant's views on the PSF tool and how the PSF concept would work in their organization is completed. The questionnaire is presented in Sect. 4.2.2. After the questionnaire, an interview is held to capture additional information regarding how knowledge management and process improvement are currently carried out at the companies and to elicit improvement proposals for PSF. During the interview, the major challenges to using PSF are also elicited.

4.2.2 Evaluation material

To collect the participants' view of how PSF would perform in their organization, a questionnaire is used. The questions used in the questionnaire are designed to answer the

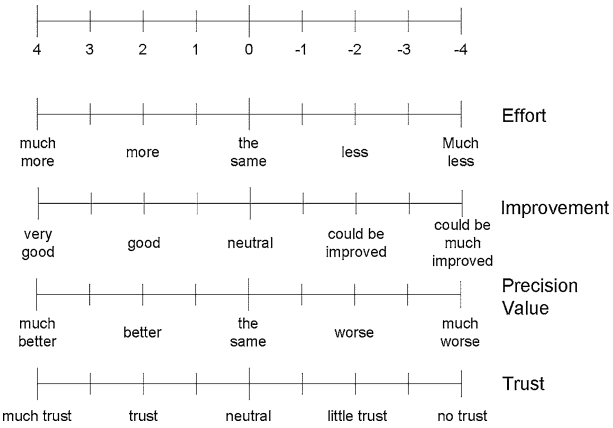

Fig. 8 Scales used in the questionnaire

research questions presented in Sect. 4.1. The performance of each task performed in the evaluation is estimated (the scales are given in Fig. 8). For each task, different perspectives are estimated: the effort of performing the task, how PSF affects the precision or ability of performing the task, and the value of using PSF for performing the task. The value of using PSF for performing a task is an estimation of the tradeoff between the added effort needed to enable the task and the value that comes from performing it. Estimating the value for using PSF provides a reality check of the estimations, i.e., even if the precision improves there is no guarantee that it will provide benefit to the organization. These perspectives have previously been used successfully in software engineering technology evaluations (Gorschek et al. 2007). For identifying good practices and improvements, an additional perspective is added: the amount of trust placed in the data that are used for making decisions. PSF relies heavily on subjective estimations of practice performance. Using subjective estimations introduces uncertainties in the data gathered. Participants are asked to estimate how much trust they would place in the subjective estimations in PSF for making decisions regarding adopting good practices and identifying improvements.

Figure 8 shows how the perspectives are converted into numbers. For example, if the subject thinks that there will be "less" effort, this answer is given the value -2. The same goes for the other scales; if a subject thinks that the value will be "better," the answer is converted into a 2, and 4 for "much better," and so on. For the results presented in Sects. 5.1 and 5.2, each perspective is summarized for each group in the evaluation, one for the academic evaluation and one for each company.

4.2.3 Operation

The evaluation is performed individually and starts with a walkthrough of the tool and an introduction to the PSF concept. Then, the participant uses the tool and estimates how PSF would affect state-of-practice. Table 2 shows the time used for each of the activities in the evaluation.

Due to time constraints, two of the industry participants could not take part in the full evaluation. Instead, a 1.5-h walkthrough and interview were held with these.

Table 2 Time distribution for the activities in the evaluation

Activity	Time (min)
Walkthrough	30
Usage and questionnaire	60–90
Interview	30–60

4.2.4 Validity

This Section discusses the threats to the validity of the study presented in this paper. As described by Wohlin et al. (2000) validity can be discussed in terms of construct, conclusion, internal, and external validity.

4.2.4.1 Construct validity Construct validity mainly concerns the mapping of the real world to the laboratory. The study presented in this paper is performed in industry with industry professionals. However, since it is limited in time and scope, and the tool and data used during the evaluation is not real, it can be seen as an artificial environment.

The main threat is scalability, i.e., if PSF will scale to work in a real environment. Scalability is to some extent covered by statements and views of the professionals in the evaluation. In addition, the data used in the tool are designed to be of moderate to good quality to mimic the situation for the intended target group, i.e., industry, and should not influence the participants unduly.

4.2.4.2 Conclusion validity Each evaluation was performed in one uninterrupted work session. Thus, the answers were not influenced by internal discussions about the questions.

The sampling technique used for selecting the participants can pose a threat to validity. However, all industry participants are experts in the area and representative of potential users of PSF.

4.2.4.3 Internal validity To ensure that the research instruments, including the posed questions, are of good quality, pilot tests with the material were executed prior to the evaluations. In addition, the measurement scales used have been successfully used in other studies.

Subjects in the evaluation not voicing their opinion during the evaluation are a threat to validity. To limit this threat, participants were guaranteed anonymity by the researcher.

4.2.4.4 External validity The external validity is concerned with the ability to generalize the results. The study presented in this paper is too small and variations between the included organizations are too large to draw any general conclusions. However, the results and especially variations between organizations points toward challenges that need to be further investigated.

5 Results

This Section presents the results from the evaluations and discusses the research questions. First, the results from the academic evaluation are given in Sect. 5.1. The industry evaluation is presented in Sect. 5.2 and addresses research questions 1 and 2. Section 5.3

presents challenges to using PSF and improvement proposals needed to improve the tool and thus address research question 3.

5.1 Evaluation in academia

The aim of the evaluation in academia is to initially test PSF before starting evaluations in industry. To ensure that results from the academic evaluation are as representative as possible for industry, PhD students participating in industry collaborations in their studies are used. The results from this evaluation are used to refine the tool prior to industrial evaluation. The participants in academic evaluation are given in Table 3.

The questions in the questionnaire concern estimating the change to current practice that would come from using PSF. The participants in the academic evaluation are asked to provide answers that reflect their understanding of industry practice from their industry collaborations. This means that the answers become specific to the companies that the students have worked with.

5.1.1 RQ 1: Is PSF usable?

With regard to the usability of PSF and the PSF tool, several aspects were estimated by the participants in the evaluation. All estimations are made on the scales presented in Sect. 4.2.2 and are summarized in this Section for all participants, which means that the maximum value for estimations is 20 and the minimum value is −20. First, the effort needed for using PSF and the resulting quality of experience documentation are estimated (shown in Fig. 7). All participants agree that PSF would increase the effort of documenting and gathering experiences. However, the increase is only expected to be minor. In return, the quality of experience documentation is expected to improve considerably. This is due to few experiences being documented today.

With regard to the usability of the PSF tool and the PSF concept, all participants agree that usage of the PSF concept would improve from having better tool support. In addition, some modifications to the PSF tool were seen to be needed to improve usability. The estimates for usability of the PSF tool and how the usability of PSF would change with sufficient tool support are given in Fig. 8.

5.1.2 RQ 2: Is PSF useful for improving practices related to diffusing good practices and identifying improvements?

The estimations related to finding good practices in the organization are given in Fig. 9. It is estimated that using PSF would lower the effort of finding out what practices work well

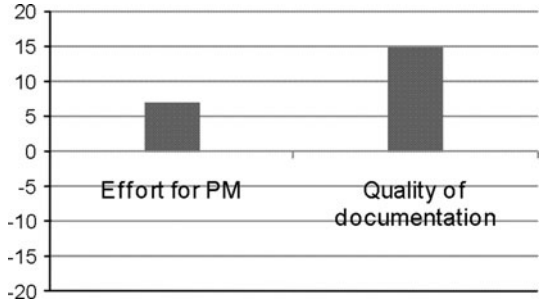

Fig. 9 Effort required for using PSF and quality of resulting experience documentation

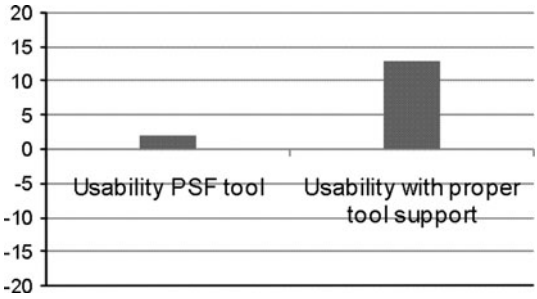

Fig. 10 Usability of the PSF tool

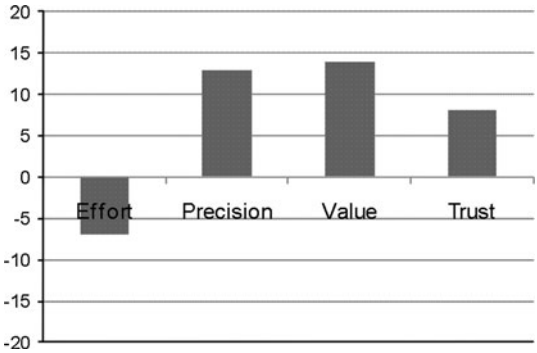

Fig. 11 Estimations related to finding practices for adoption

in the organization and that the precision in finding out what practices work well in the organization would improve. The participants also estimate that enabling finding out what practices work well would provide value to the organization, e.g., by diffusing good practices.

It is also estimated that the subjective estimations used as decision support in PSF are trustworthy in identifying good practices. As long as subjective estimations are only used to discern what has worked well in a project, they are seen as trustworthy. However, it might be hard to discern changes in practice performance over time or between projects.

For identifying improvements, the results are similar to identifying good practices (see Fig. 10). However, the value for identifying good practices is estimated to be higher than for identifying improvements.

PSF is also seen to provide value in identifying experiences from specific projects (see Fig. 11). Projects can identify similar previous projects and use the experiences from these as input, i.e., practices that have worked well in similar projects might be useful in new projects.

PSF is also estimated to provide a better overview of knowledgeable persons in the organization (see Fig. 12). In comparison with other knowledge management approaches for mapping competence and knowledgeable persons (Dingsøyr and Conradi 2003; Broessler 1999), PSF also provides context and valuation to the experiences that persons have. This means that it is easier to identify persons who have experiences from similar contexts, e.g., similar problems.

Overall, the results from the academic evaluation are positive. All perspectives of PSF usage are estimated to provide value over current practices. Improvements suggested to the PSF tool were implemented after the evaluation. All improvements are related to providing a better overview of experiences and projects in which they have been used.

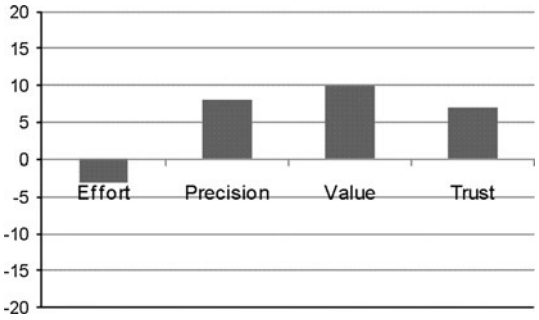

Fig. 12 Estimations related to finding improvement potential

Table 3 Participants in the academic evaluation

ID	Research area
A1	RE, SPI
A2	Cost estimation
A3	RE, test
A4	SPI, RE, test
A5	Test

For all estimations presented in this section, all but one participant were unanimous. Participants A1–A4 all had similar estimations while participant A5 estimated that that using PSF would not provide any change, except for adding effort for documenting experiences.

5.2 Evaluation in industry

Since the evaluation in academia showed promising results, the evaluation was moved into industry to collect feedback on applicability. The evaluation involves three different companies given in Table 4. The reason for including several organizations in the evaluation is to investigate how different organizations improve and diffuse good practices and what factors influence PSF usage. The companies were chosen as they all are geographically distributed. In a localized organization, experiences and practices are often exchanged by word-of-mouth.

At C1 and C2, two full evaluations, as described in Sect. 4.2, were carried out. In addition, a walkthrough of the PSF tool and interview was conducted in organizations C1 and C3. The reason for not carrying out the full evaluation was due to time constraints. The subjects are described in Table 5. The subjects were chosen based on expertise and experience.

5.2.1 RQ 1: Is PSF usable?

Starting with company C3, the effort of using PSF is seen as too high to be a viable solution. The company is small (about 50 employees) and documenting practices and experiences is seen as adding too much overhead. However, C3 still capitalizes on experiences in the organization. Best practices are diffused by senior staff moving from site to site. In addition, as experienced employees have high mobility, these also have a strong contact network and everyone knows whom to ask when faced with issues. The threshold for initiating contacts is lowered by first having had face-to-face contact. Company C3 manages to retain knowledge and experience in the company by having low staff turnover for senior personnel.

Table 4 Companies in the evaluation

Company	Size	Project size	Products	Projects	KM and SPI approach
C1	1,000+	Large projects (100+ persons over several years)	Systems	A few different types of projects. Many projects of similar type.	C1 uses a prescribed set of processes and practices in all projects. The process is documented in an EPG. C1 uses CMMI for process assessment and postmortems to learn from projects. In addition, an issue tracking system is used to document methodology and tool issues encountered in projects
C2	1,000+	Medium (10–30 persons over 1–2 years).	Embedded software and systems	A few different types of projects. Many projects of the same type.	C2 uses a prescribed process but chose development practices on a per product basis. The process is documented in an EPG while practices are documented in a wiki for easier modification. C1 uses CMMI for process assessment and postmortems to learn from projects
C3	~50	The project size varies. In-house projects for customers are usually small (1–5 developers over a couple of months). Staff takes part in projects of all sizes as consultants.	Consultancy, Software systems The company both sells person-hours to clients and develops software as a supplier.	Different	Internal development follows a tailored SCRUM (Schwaber 1995) process. Practices are informal and based on knowledge and expertise of staff. Experienced staff move from site to site and thus a contact network is upheld in which experiences and best practices are shared

Table 5 Participants in the industry evaluation

ID	Company	Responsibilities	
I1	C1	RE, architecture, SPI	
I2	C1	RE	
I3	C1	PM	Only interview
I4	C2	PM, RE	
I5	C2	PM, RE	
I6	C3	PM	Only interview

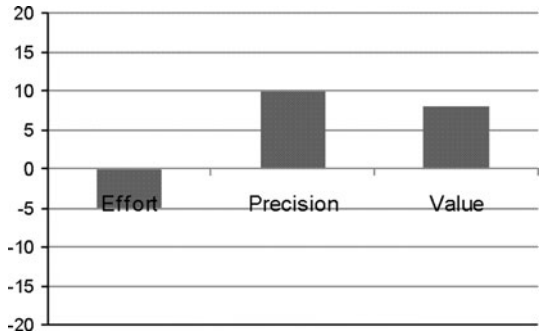

Fig. 13 Estimations related to finding experiences from particular projects

When it comes to companies C1 and C2, the perceived effort and quality of documentation compared with today are given in Fig. 13 for both companies. The estimations are the summary of two persons at each company, and thus the maximum value is eight and the minimum is minus eight. The effort is expected to increase at both C1 and C2, while the quality of experience documentation is expected to improve. Both companies currently use postmortems to capture and analyze experiences from concluded projects. Experiences captured often relate to process, customer, and product issues, and the added effort is seen to come from identifying and documenting experiences from practices. Today, practices are often only judged implicitly in postmortems.

Figure 14 shows that the estimations for usability of the PSF tool and PSF usage would change with improved tool support. Both companies estimate that PSF usage would improve with better tool support. The main area of improvement involves finding relevant experiences faster and is further discussed in Sect. 5.3.2. In addition, it was argued that not only process and project managers are responsible for ensuring that projects learn from the organization's experiences. Everyone should take part in leveraging experiences inherent to the organization. This increases the importance of usability, as not only a few experts should be able to use the tool.

Summary of RQ1 To summarize research question 1, the initiation threshold for using PSF is perceived as being high if practices are not already documented in the organization. In addition, tool support for PSF needs improvement to make it practically usable. More support is needed for finding and evaluating relevant experiences. Potential improvements are discussed in Sect. 5.3.2. Having insufficient tool support in the evaluation might affect the validity of the estimations. As the usability of the tool is estimated to need improvement, other estimates might be influenced negatively. There is also a noticeable difference in valuation between companies C1 and C2. C2 is more positive to PSF usage on all perspectives for research question 1.

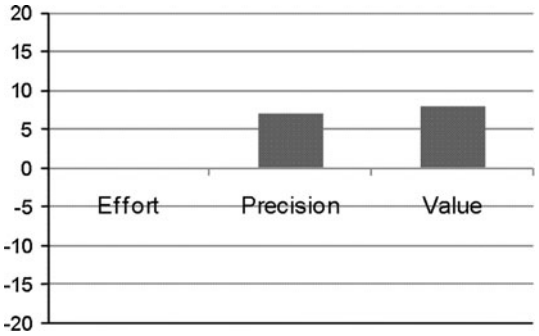

Fig. 14 Estimations related to finding knowledgeable persons in the organization

5.2.2 RQ 2: Is PSF useful for improving practices related to diffusing good practices and identifying improvements?

PSF can support diffusing good practices and identifying practices that need improvement. For sharing good practices, these are currently shared with persons that you have contact with at both C1 and C2. At both companies, this means that practices and experiences from using these are seldom shared with other sites. However, using PSF to share good practices is estimated differently at the companies (see Fig. 15). At C1, sharing practices is estimated to add no value. Even if PSF alleviates finding practices to adopt, the participants do not expect that practices would be adopted. At company C2, PSF is seen as supporting finding practices that have worked well in other places in the organization. Currently, practices at C2 are decided on a per product basis. Experienced staff at the site meet and decide on what practices to use or if new ones need to be developed. Using PSF it is expected that practices used in other parts of the organization can be used as input to this activity, and that potential new practices to use can be found. The effort of finding out what has worked well in other projects is expected to decrease, and PSF is expected to add value for identifying good practices. However, the value is dependent on the practices available. There needs to be a gap between different parts of the organization to leverage practices, i.e., there need to be practices that add enough value to transfer. At company C2, this is expected to happen occasionally.

For finding improvement potential, both companies C1 and C2 estimate usage of PSF in a similar way (see Fig. 16). PSF is expected to have little impact on finding improvement potential. However, the reasons for the valuations are different. At both companies, there is

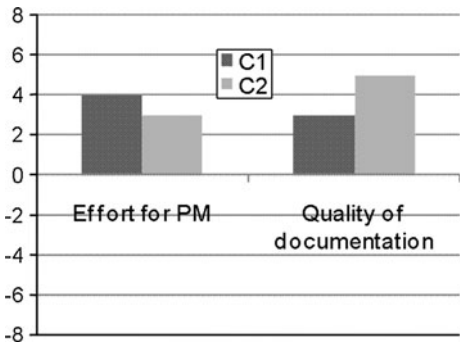

Fig. 15 Effort required for using PSF and quality of resulting experience documentation

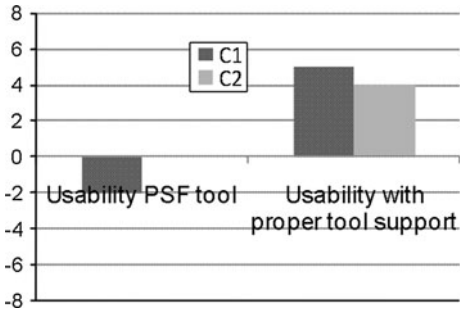

Fig. 16 Usability of the PSF tool

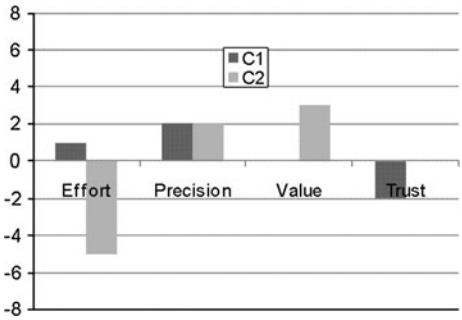

Fig. 17 Estimations related to finding practices for adoption

already a good understanding of what needs to be improved in individual projects. At C1 where practices are prescribed, using experiences collected in postmortems is not seen as reliable enough to make changes affecting practices used organization-wide. At C2, there is no need to make improvements known on the organizational level. Improvements deemed important enough are handled in the project. This is possible as practices only affect the individual project. However, at both C1 and C2, improvements initiated on the project level are localized to the project in which they are implemented. Experiences from them are only shared within the project or site at which they are implemented (Fig. 17).

At company C2, a potential benefit of using PSF is to enable evaluating practices over project boundaries. For instance, reuse of requirements needs to be evaluated by considering both the project in which reusable artifacts are produced and the projects that use them. This is currently not handled at C2.

Similar to identifying practices that have worked well in other projects, companies C1 and C2 differ on the estimations for using PSF to identify practices and experiences from similar projects. At C1, identifying similar projects and practices used in these are not seen to add value, as the experiences are not expected to be used. Project managers use white books from previous versions of products, i.e., projects that are directly related to the product, as input to new projects. However, aside from project management, experiences from other projects are seldom used as input to how to conduct development, except for the experiences that individuals bring to the project. This is largely due to practices being prescribed, i.e., all projects officially use the same practices. However, informal practices are used when circumstances in projects, often time pressure, makes prescribed ones unfit. These are not documented but based on knowledge possessed by staff in the project. The decision on how to proceed when prescribed practices are not usable thus depends on the staff in the project.

One example from the interviews is a practice for reviewing requirements. C1 uses a quite ambitious requirements-review practice that, if used often, produces good results. As it is ambitious, it requires much effort to use. Some projects omit requirements reviews because the resources are not available, while other projects use a scaled-down review practice to ensure some verification of requirements. It is seen as important to have not only the prescribed practice documented, but also alternatives that can be used when the prescribed one is not usable. However, these practices need to be managed and caution taken not to institutionalize practices to cope with situations that need to be addressed (Jørgensen and Sjøberg 2000). Thus, a lack of time in projects might indicate that the prerequisites for the project or estimation practices do not work satisfactorily.

At C2, gaining access to practices and experiences from similar projects is seen as important, and PSF is estimated to add value for this activity. Currently, experiences from previous versions of the same product are used both explicitly, as input using white books, and implicitly by staffing the project with persons who have experience from the product. PSF would enable finding out what practices are used in similar projects and experiences from using these. At C2, it is estimated that practices used in projects developing different products but under similar conditions could be used in new projects. Gaining access to what practices have been used in similar projects, and experiences from using these, could influence the decision on what practices are used.

The part of PSF that is estimated to add most value is adding traceability to persons in the organizations who have experience from using specific practices in specific contexts (see Fig. 18). Enabling persons to be identified who have experiences from practices, and being able to evaluate the context in which the experiences have been gained, are seen as important. Adding traceability to knowledgeable persons enables sharing tacit knowledge. However, at both C1 and C2, it is seen as important not to be too intrusive on ongoing projects; thus, documentation is important for transferring knowledge. Figs. 19 and 20.

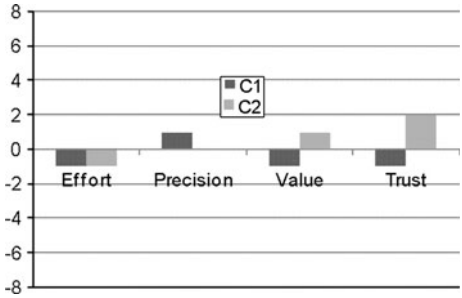

Fig. 18 Estimations related to finding improvement potential

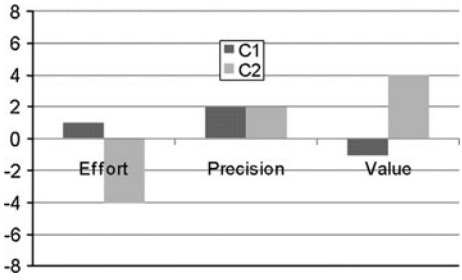

Fig. 19 Estimations related to finding experiences from particular projects

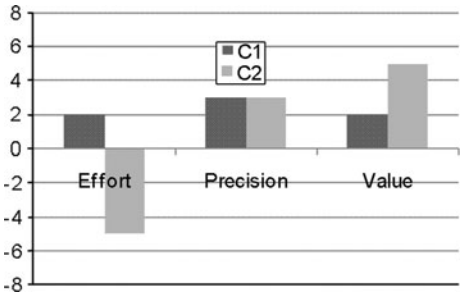

Fig. 20 Estimations related to finding knowledgeable persons in the organization

Summary of RQ2 To summarize the results for research question 2, it seems that the use of practices to transfer knowledge is dependent on organizational characteristics. Company C1, which has prescribed practices, does not estimate that practices or experiences from using these are likely to be shared. However, at C2 where practices are chosen by the project, and documented to reflect usage of them, making practices and experiences from using them available to other projects is estimated to add value. Still, practices are not expected to be transferred as is, but rather to be an inspiration for how to tailor practices used in projects. Experiences collected in postmortems are expected to have a limited influence on improvements to practices used throughout the organization, i.e., prescribed practices.

These results both corroborate and add to previous work on using formal routines to transfer knowledge (Conradi and Dybå 2001). In organizations where practices are used to certify the company, i.e., not to reflect actual practice, their usefulness to transfer knowledge is seen to be limited. This study shows that organizations that have practice documentation that reflects practice might benefit by sharing knowledge and experiences from these.

5.3 Discussion of the evaluations

This Section presents challenges and improvements collected at the companies. Section 5.3.1 addresses research question 3 and presents challenges to PSF usage. Section 5.3.2 presents the improvements seen as necessary to improve PSF and the PSF tool. Finally, the differences between the evaluation in academia and industry are discussed in Sect. 5.3.3.

5.3.1 Challenges to PSF usage

The evaluation revealed that PSF is faced with many of the same problems as other improvement and knowledge management approaches (Pettersson et al. 2008; Bjørnson and Dingsøyr 2008; Gorschek and Wohlin 2004). The challenges uncovered in the evaluations are:

- Dedicated resources for change.
- Resources for documentation.
- Trust.
- Legacy.
- Measurement.

PSF is developed to be lightweight in adding low overhead for identifying improvements and learning from success (Nolan 1999). Still, without dedicated resources for change, the effort will be in vain. This is the case at C1 where, today, even the most urgent improvement needs suffer from a lack of dedicated resources. At C2, changes happen and practices are chosen on a per product basis. At C2, the added resources needed for using PSF are estimated to add value in leveraging the organization's experiences regarding practices used, since resources are available to capitalize on them, i.e., if a practice used in the organization is perceived to be beneficial, it will be adopted.

Organizations that do not currently have documentation of practices will most likely not be able to use PSF. The idea is that the practice contains most of the knowledge to be transferred. If practices are not currently documented, or the documentation does not reflect practice, the effort and resources needed to implement and run PSF will probably be too high.

Trust is a major determinant in having a successful knowledge management approach. If people do not trust each other's experience or do not value it, learning will not take place. This is the case at C1 where only trusted persons affect decisions regarding what practices to use. At C2, trust is not seen as an issue. If the conditions under which a project has been carried out are understood, the experiences from it are considered to be trustworthy. Having an understanding of the product and the customer, it is being developed for is seen as important for valuing experiences at C2.

Legacy is also limiting the potential for change. Products are seldom developed from scratch, and the legacy from previous products in the form of the product itself and related artifacts needs to be considered. Legacy influences the resources needed for changing practices. Changing the way requirements are specified might mean having to reengineer the specification, while adopting a new practice for reviewing requirements might be a small investment. This challenge is most notable at company C1 where large projects are carried out.

Central to PSF is using subjective estimations to discern practices that work well and ones that can be improved. At both C1 and C2, postmortems are successfully used to identify improvement needs in projects. However, it is also seen that complementary approaches such as traditional process assessments are needed, in order to focus not only on immediate project issues. For PSF, one issue is whether subjective estimates are good enough for discerning practice performance. In the evaluation, reliability of measurements was considered an issue determining the use of postmortem data. It is seen as important that the experiences collected do not only represent individuals' perception. Thus, ensuring validity of experiences collected is important (Pettersson et al. 2008). For improvements, subjective estimations are thought reliable enough to change the project in which the issue is uncovered, or the following project, but not to change organization-wide practices. For identifying good practices, subjective estimations are considered reliable. Nevertheless, even if a practice is estimated to have performed well in a similar project, there is no guarantee that it will work well in another project. PSF can, however, provide additional input for deciding what practices to use. Integrating experience capture into regular engineering processes using postmortems is also seen as important. Experiences regarding practices are not expected to be documented and shared without a mandate from management.

One additional problem with subjective estimations is that it is hard to use these as input to quantify the potential return on investment of using new practices. This might lower the commitment for adopting new practices. Practices that have been very successful in other

projects might be picked up by others, but these are estimated to come along less frequently than small improvements.

5.3.2 *Improvement proposals for PSF*

During the evaluations, improvements needed to make PSF applicable in practice were discussed with the participants. The major improvements to PSF are listed below:

- Effort of using PSF.
  - Effort of finding relevant experiences.
- Practices.
  - Definition of practices.
  - Documentation of practices.

The effort needed to find relevant practices and experiences needs to be lowered for PSF to be usable. If users do not immediately find relevant experiences, or if they find an overwhelming number of experiences without a proper overview or summary, there is a risk that they will abandon its use (Lindvall et al. 2001). The structure of the experiences, i.e., the process view where experiences are related to processes, was valued during the evaluation. Retrieving experiences is a goal-oriented activity and users need to be able to locate relevant experiences easily. To improve usability enabling browsing, the process for practices and experiences in the context of similar projects are needed. Only viewing experiences and practices from similar projects limits the effort needed to analyze the information available. On the other hand, only viewing experiences from similar projects might also miss relevant experiences. Thus, users need to be able to choose what project attributes are important for the practice they are looking for. A review practice might not be influenced by the context in which it is used, and thus all other projects can be considered—while a practice for specifying requirements might not scale to all sizes of projects, and only projects of similar size might be considered. Expert users should thus be able to choose what project attributes they consider to affect practice performance, and view projects that have similarities on these attributes, while novice users can select only to view similar projects. In addition, specifying practice performance from several perspectives was seen as important in the evaluation. Different projects have different priorities, and enabling finding practices that support the priority of, e.g., quality or cost was seen as important. The current overview of performance attributes, i.e., ranked lists for each performance attribute, is not seen as good enough. Instead, users should be able to provide the priorities for the current project and get a summarized performance overview for practices. In addition, some additional attributes need better overview, e.g., a composite of pros and cons for specific practices. Currently, users need to access each experience in the PSF tool to view all pros and cons collected for a specific practice.

An issue with using practices to disseminate experiences is that practices are very concrete ways of performing activities. This means that different projects will use slightly different practices. Instead of having each project document it as a new practice, hierarchies of practices are seen as a solution in order to keep the repository structured and to avoid having experiences fragmented over several slightly different practices.

Additional improvements include documenting dependences between practices, i.e., the use of a practice depends on using another. Prerequisites for the use of a practice, e.g., a practice used for a product line, might not be usable for single system development.

5.3.3 Industry and academia

The results from the academic and industrial evaluations are different. In academia, PSF is estimated to provide higher value than in industry. One explanation is that PhD students taking part in the evaluation all perform studies in contexts similar to company C2. However, there is still an overestimation regarding documenting experiences to use for improvements. In the industry evaluation, documenting experiences to use for improvements was estimated to add little value, as staff working in the project often already understand problems. However, a lack of resources often hampers realizing improvements since development is given priority over improvements. Using students in evaluations might thus show that improvements are possible, but not that they will actually occur in industry. Thus, care should be taken when using students in process improvement or knowledge management evaluations.

6 Conclusions

This paper presents tool support for Practice Selection Framework (PSF). PSF is an Experience Factory approach aiming to bridge the gap between different parts of the organization and share experiences regarding practices between these.

The tool was used in an initial evaluation of PSF. The evaluation aimed to collect feedback on challenges for implementation and improvements to PSF and the tool. The evaluation was limited in scale, and more participants evaluating PSF, and the tool are needed to ensure validity of the results. However, given the challenge of getting real industry practitioners to participate in a validation, this validation can be seen as a promising first step, where the actual design of the tool as well as the design of the validation are parts of the contribution.

The initial results indicate that to enable PSF usage, organizations must already have a high degree of practices documented. Otherwise, the initiation threshold and effort needed to use PSF are too high. However, utilizing already existing documentation, and transferring it to PSF, is a low-cost way of sharing knowledge.

Experiences collected in postmortems are not estimated to affect improvements to practices used organization-wide. However, if organizations use different practices in different parts of the organization, making practices available with experiences from usage, as well as context information, could influence decisions regarding what practices to use. Practices used in other parts of the organization add to the number of potential practices to use in projects. In addition, evaluating practice performance from different perspectives can aid projects in selecting practices when projects' priorities change.

The challenges for diffusing practices point toward the trust placed in others' experiences and resources available for change. Experiences are not likely to be used if they are not trusted. However, even if experiences are available and trusted, resources are needed to realize changes. Small changes are expected to happen without dedicated resources, but larger ones need commitment from management. Related to tool support, improvements are needed to enable practitioners to find relevant experiences quickly. There is a risk that

PSF will be abandoned if practitioners cannot quickly decide whether usable experiences exist in PSF.

Future work with PSF includes creating a stability index pertaining to practices, which would enable practitioners to gauge the reliability of a practice. In addition to this, efforts are under way to pre-fill PSF with good practices, available as input to practitioners looking to solve or handle a specific task. As these efforts are undertaken, further validation is planned.

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