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Published in:
Proceedings of the 11th IEEE International Conference on Global Software Engineering

DOI:
10.1109/ICGSE.2016.10

Publication date:
2016

Document version
Accepted manuscript

Document license
Unspecified

Citation for pulished version (APA):
Kuhrmann, M., Diebold, P., Münch, J., & Tell, P. (2016). How does Software Process Improvement Address Global Software Engineering? In *Proceedings of the 11th IEEE International Conference on Global Software Engineering* (pp. 89-98). IEEE Press. https://doi.org/10.1109/ICGSE.2016.10

How Does Software Process Improvement Address Global Software Engineering?

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***Abstract*—For decades, Software Process Improvement (SPI) programs have been implemented, inter alia, to improve quality and speed of software development. To set up, guide, and carry out SPI projects, and to measure SPI state, impact, and success, a multitude of different SPI approaches and considerable experience are available. SPI addresses many aspects ranging from individual developer skills to entire organizations. It comprises for instance the optimization of specific activities in the software lifecycle as well as the creation of organization awareness and project culture. In the course of conducting a systematic mapping study on the state-of-the-art in SPI from a general perspective, we observed Global Software Engineering (GSE) becoming a topic of interest in recent years. Therefore, in this paper, we provide a detailed investigation of those papers from the overall systematic mapping study that were classified as addressing SPI in the context of GSE. From the main study's result set, a set of 30 papers dealing with GSE was selected for an in-depth analysis using the systematic review instrument to study the contributions and to develop an initial picture of how GSE is considered from the perspective of SPI. Our findings show the analyzed papers delivering a substantial discussion of cultural models and how such models can be used to better address and align SPI programs with multi-national environments. Furthermore, experience is shared discussing how agile approaches can be implemented in companies working at the global scale. Finally, success factors and barriers are studied to help companies implementing SPI in a GSE context.**

***Index Terms*—global software development; software process improvement; systematic mapping study; systematic literature review**

I. Introduction

Software development is commonly considered a complex and challenging activity. To organize software development, for decades, companies have been looking for *Software Process Improvement* (SPI; [1]) allowing them to analyze their development approaches and continuously improve them. In the course of conducting a systematic mapping study [2], [3], SPI was mentioned a diverse field: many SPI facets are studied, several hundreds of custom SPI approaches were proposed, e.g., to address weaknesses of standard approaches like CMMI [4], SPI success factors are collected and analyzed, and new trends such as SPI in the context of VSEs and SMEs, and SPI employing agility as improvement principle (also in the context of large global players) are addressed.

In general, SPI is considered highly relevant for companies of all sorts and sizes [5]. But, SPI is also a risky endeavor, generating cost and effort, always facing the risk of disrupting an organization (e.g., by faking processes [6] or implementing inappropriate processes to please an assessment goal rather than the organization's needs [7]). Also, these challenges are put to a new level when SPI is applied to global endeavors. SPI in the "classic" (co-located or team-based) sense pretty much deals with people—actually, SPI is mainly about the way people collaborate. This becomes an issue in Global Software Engineering (GSE), as there is no longer "the only one" culture to be addressed. For instance, in [8] author conclude that the same SPI measures are differently perceived and implemented at different sites of even one company.

A. Problem Statement & Objectives

The literature on SPI is rich—it is full of proposals and best practices. However, SPI is also critically discussed, notably so-called standard approaches, such as CMMI or ISO/IEC 15504, are considered critical. Within this lively discussion, software and systems development changed—it went global. However, although being subject to research for a while and being considered of certain relevance [9], little is known about how GSE is perceived from the SPI perspective. The present research aims to shed some light on SPI in the GSE context. The starting point is a comprehensive systematic mapping study (Sect. I-B), which we filtered for publications explicitly addressing GSE issues. The objective of this research is thus to analyze literature to present the big picture on SPI in GSE and to provide a state-of-the-art report.

B. Context: A Systematic Mapping Study on SPI

This study is grounded in a comprehensive systematic mapping study on the state of Software Process Improvement (SPI) of which initial findings where published in [2][1]. Outcomes of this study show SPI being an actively researched topic, yet lacking theories and models. Instead, the field of SPI is shaped by a constant rate of approx. 10-12 new SPI models per year. In the course of updating the study [3], we used trends observed in the initial data analysis to form topic clusters of which one cluster addresses Global Software Engineering. The study at hand refers to this subset of the main study [3], which is devoted to GSE (cf. Sect. III).

[1]**Note:** The study is currently in the updating process [3]. Latest (raw) data and a preliminary report are available on request.

C. Contribution

Our study shows how GSE is treated from the perspective of "pure" SPI and, therefore, our study contributes to both the SPI- and the GSE-related body of knowledge. The 30 analyzed papers are mostly classified as philosophical papers, i.e., they discuss known concepts from different angles, or transfer and compare solutions/proposals in a new context. Nonetheless, the analyzed papers are rated to be of high and very high relevance to industry. In particular, in the context of GSE, SPI mostly deals with culture and management issues, and researchers as well as practitioners are seeking for appropriate solutions to scale agile methods to GSE, and to find and study SPI barriers and success factors.

D. Outline

The remainder of the paper is organized as follows: Sect. II provides an overview of work related to our study. Section III describes the research design by relating the present study to the main study and presenting the details on the specific methods applied. In Sect. IV, we present the study results by presenting the big picture and answering the research questions, before discussing the findings and the threats to validity. We conclude the paper in Sect. V

II. Related Work

In SPI, different topics are researched in secondary studies. For instance, Monteiro and Oliveira [10], Bayona-Oré [11], and Dybå [12] study SPI success factors, while Helgesson et al. [13] review maturity models, and Hull et al. [14] and El-Emam and Goldenson [15] review different assessment models. These exemplarily mentioned studies show that the SPI community has started the search for generalizable knowledge. Yet, the mentioned studies address more general SPI issues thus not making GSE a first-class citizen. Contrasting, the study at hand limits the perspective to GSE thus adding extra barriers and success factors to the body of knowledge that explicitly address those themes in the light of GSE. Related SPI literature also discusses custom or new approaches to address SPI in specific contexts. For instance, Staples and Niazi [16] study motivating factors to adopt CMMI for improvement programs, while Müller et al. [17] study SPI in general from the perspective of organizational change. Especially Staples and Niazi [16]—by reviewing motivators—lay the foundation for a number of contributions with particular relevance to SPI in emerging countries in Asia and Arabia. In the present study, this topic is of certain relevance, as GSE expands software development to countries not yet having high process-related maturity, which therefore need to catch up with the "developed countries" in order to allow for setting up distributed projects.

All these representatively selected studies address specific topics, yet, they do not contribute to a more general perspective on SPI in the context of GSE. The paper at hand thus fills a gap in literature by collecting and analyzing publications that emphasize SPI in the GSE context and, therefore, also lays the foundation to direct future research in this field in SPI research.

III. Research Design

The present study is an in-depth analysis of a data subset identified in a more comprehensive systematic mapping study [2], [3]. In this section, we describe how this subset was formed and how the presented research was conducted.

A. Research Questions

In the course of analyzing the selected GSE-related papers, this study aims to answer the following research questions:

RQ 1	What is the study population on SPI with a special focus on GSE?
RQ 2	What are the topics addressed by SPI for GSE?
RQ 3	What topics are addressed in the different regions of the world, and what is the respective contribution and the contribution's maturity?

B. Data Collection Procedure

Being a study on a data subset, in this study, we had no need for an explicit and self-contained data collection. Input data was obtained from the main study's result set [3], which we refer to as the study's *raw data*. The selection of the data of interest in the raw data was carried out by selecting all publications from the raw data having the metadata attribute "GSE" set (Fig. 4). This initially results in 37 publications.

The resulting subset (to which we refer to as the *study data*) was then copied to an own spreadsheet. To improve the reliability of the data analysis, an external researcher joined the team, while two researchers took over quality assurance tasks. That is, the study analysis was carried out in two teams. Having the study data available, in the course of downloading all selected papers, an initial quality assurance was performed. This quality assurance led to the exclusion of 7 papers for the following reasons: One paper had to be excluded due to changed availability, i.e., this particular paper was no longer available for download. Six more papers were excluded after full inspection, as they were found misclassified, e.g., by misleading terminology. Those papers' metadata were updated, such that they will be returned to the main study (Sect. V).

Eventually, **30** papers remained in the cleaned study data set, which where then analyzed as described in Sect. III-C.

C. Analysis Procedure

As "preparatory" study with the purpose of getting the big picture, the main study was conducted as a systematic mapping study following the guidelines as proposed by Petersen et al. [18]. The present study however aims to deliver more insights and details and, thus, is carried out using the systematic review instrument as described by Kitchenham and Charters [19].

In particular, during the paper download and quality assurance, the initial metadata set was revisited and, if necessary, updated. Furthermore, every paper was inspected by two researchers, who developed a paper summary of 2-3 sentences. These summaries were used to develop a study-specific classification schema (we use the term *focus type facet*, cf. Paternoster et al. [20]). Based on this specific schema,

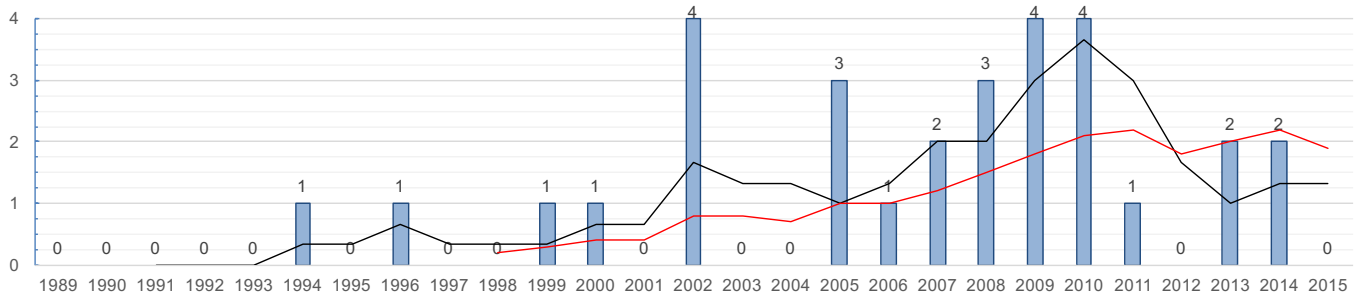

Fig. 1. Number of papers published over the years ($n = 30$), including a 3-year trend (black line) and a 10-year trend (red line).

we (i) extended the data analysis and presentation of the main study and (ii) conducted the in-depth analysis. Finally, to evaluate the papers regarding their rigor and relevance, we applied the model proposed by Ivarsson and Gorschek [21] to round out the picture.

D. Validity Procedures

To improve the validity of the results, we applied the following measures: First, we called in an external researcher and formed two teams. Team 1 conducted the data analysis, while team 2 was taking over the quality assurance. Second, in the data analysis, team 1 reapplied the procedures of the main study [2], [3], i.e., all papers were re-inspected to check the correct assignment and—if necessary—to complete the assignment of the 40 metadata attributes (cf. Fig. 4 for an overview). Third, the inspection and attribute assignment was carried out using the *systematic review* instrument using the full text of the study-relevant papers.

IV. Results

In Sect. IV-A, Sect. IV-B, and Sect. IV-C, we present the study results addressing our research questions. The results are then discussed in Sect. IV-D.

A. RQ 1: Study Population

We start with presenting the study's demographics to provide an overview of the result set.

1) Publication Frequency: Figure 1 shows the publication frequency of the studied papers. In total, the study data comprises 30 papers published between 1994 and 2014. The data shows that SPI as a research field addresses GSE, yet the figure does not show a constant publication rate, i.e., GSE is only addressed "from time to time", as the two trend lines show. However, taken the 20 years in which papers were published on this topic, in average, 1.5 papers per year are published on SPI in the GSE context. Moreover, the number of papers started increasing around 2005/2006, when the ICGSE conference series started [9] (see also Sect. IV-D2).

2) Research- and Contribution Type Facets: To classify the papers, we applied the research type facet (cf. Wieringa et al. [22]) and the contribution type facet as used by Petersen et al. [18]. Both classification schemas are used to generate the systematic map shown in Fig. 2. The map shows the majority

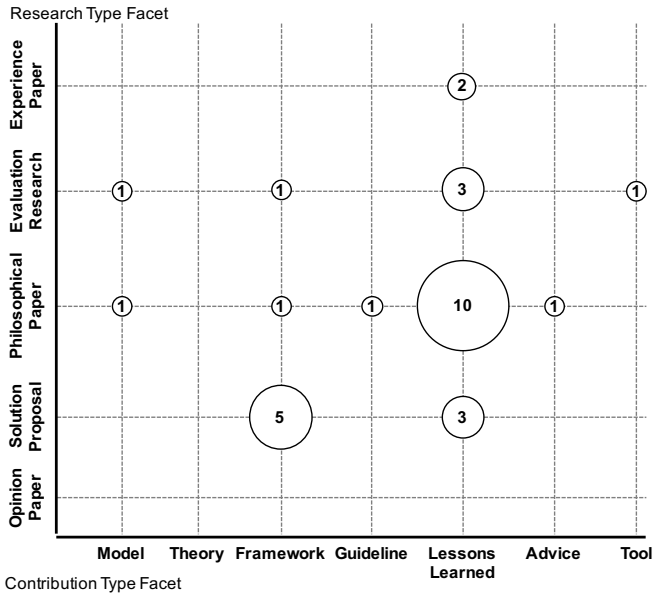

Fig. 2. Overview of the research type facets and contribution type facets in the study dataset.

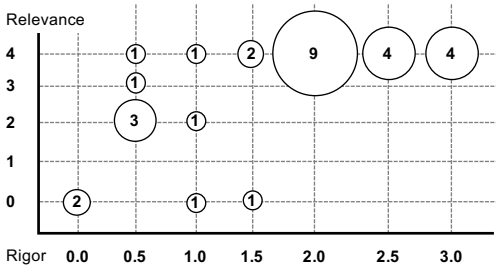

Fig. 3. Rating of the relevance to industry and the rigor of the research method applied of the papers in the study dataset.

(14 out of 30) of the papers classified as *philosophical paper*, i.e., papers providing a discussion of concepts from different perspectives, papers that discuss the transfer of a concept from one domain into another one, or papers reporting secondary studies, such as systematic reviews. Another eight papers are classified as *solution proposals*. Regarding the papers'

			Total	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Dimension: Proce	Publication Objective	Agile/Lean	5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0
		Process Simulation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Process Line/Patterns	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Product Line/Management	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Success Factors	13	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	1	4	0	0	2	0	0
		Custom Model	10	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	3	0	0	0	1	2	0
		General Improvement	19	0	0	0	0	0	1	0	1	0	0	1	1	0	3	0	0	2	0	2	2	2	2	1	0	1	0	0
	Assessment and Ass. Models	CMMI	12	0	0	0	0	0	1	0	0	0	0	1	0	0	2	0	0	1	1	1	0	3	2	0	0	0	0	0
		ISO/IEC 15504	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
		General Measurement	11	0	0	0	0	0	1	0	1	0	0	1	0	0	3	0	0	1	1	1	1	0	0	0	0	0	1	0
	(Quasi-) Standards (and Techniques)	Six Sigma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Bootstrap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		CompetiSoft	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Continuous Improvement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		PSP/TSP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		ISO/IEC 29110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		ISO/IEC 12207	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimension: Study Typ and Method		Survey/Interview	21	0	0	0	0	0	1	0	0	0	0	0	1	0	3	0	0	2	1	1	3	4	3	0	0	1	1	0
		Single Case-Study	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0
		Multi-Case/Long. Study	10	0	0	0	0	0	1	0	0	0	0	0	1	0	2	0	0	1	1	0	0	2	1	0	0	0	1	0
		Replication Study	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		SLR/SMS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Grounded Theory	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Dimension: Conte	Life Cycle Phase	Project Management	9	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	1	2	1	0	1	0	0
		Quality Management	9	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	1	0	1	0	1	0	0	1	1	0
		Requirements Engineering	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
		Architecture	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Implementation	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Test	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
	Company Size and Scale	VSE/SME	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
		Other Company Size	14	0	0	0	0	0	1	0	0	0	0	1	1	0	1	0	0	1	1	0	1	2	3	0	0	1	1	0
		GSE	**30**	0	0	0	0	0	1	0	1	0	0	1	1	0	4	0	0	3	1	2	3	4	4	1	0	2	2	0
	Application Domain	Embedded Systems	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
		Telecommunications	5	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
		Medical Devices	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Automotive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Mission-critical Defense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Business IS	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	0	0	1	1	0
		Web/Mobile/Cloud	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
		Skills and Education	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Fig. 4. Overview of the metadata attributes and there mentions over time. The attribute "GSE" serves as selector for the study at hand.

contribution, seven papers provide *frameworks* (or methods), and 18 papers summarize and discuss *lessons learned*. Given the findings from the main study, Fig. 2 shows the same trend in the studied papers, i.e., the majority of the SPI papers is classified as solution proposal or as philosophical paper, and the majority of the contributions are new and/or custom SPI frameworks and lessons learned.

3) Relevance and Rigor: To analyze the rigor and relevance of the selected papers, we applied the rigor-relevance model, as described by Ivarsson and Gorschek [21]. Figure 3 shows the rating of the papers according to this model (cf. Table I). The rating shows 13 out of 30 papers rated of very high relevance, and high to very high rigor in the research methods applied. According to the used model, about half of the papers analyzed report highly relevant content, i.e., knowledge is related and/or directly applied to (industrial) practice.

B. RQ 2: Addressed Topics in SPI for GSE

In this section, we answer the research question for the topics addressed in SPI-related papers in the context of GSE. For this, we ground our analysis in the metadata attributes collected in the course of classifying the papers (in the main study and in the refinement presented here). To provide a fine-grained classification, we defined 40 metadata attributes in

total. Figure 4 shows the attributes and the assignments for those papers that were considered in the present study. The figure shows several peaks, and also sheds light on the detailed topics addressed and the relevance of these topics over time. In particular, Fig. 4 shows that most of the papers address SPI in terms of a *general improvement* (19 mentions), whereas further topics are related to this general improvement, such as standard SPI models like CMMI (12 mentions), or efforts considering *general measurement* (11 mentions). Furthermore, we find GSE-related research on SPI mostly reported from large companies (14 mentions), whereas VSEs and SMEs were not that present in the result set. Lifecycle phases considered the most in the studied papers are project management and quality management (9 mentions each).

Summarizing, the picture from the analysis of the collected metadata, SPI in the context of GSE is mainly driven by large companies, addresses the project- and quality management, and aims to develop custom/new SPI approaches specific for the field, but also grounded in standard approaches. Furthermore, success factors are addressed by the studied papers.

With the observed trends, the scoped study at hand to a large extend follows the trends found in the main study [3]. That is, the focal points of the research on SPI are custom/new models specific to the respective context. However, one trend that could be observed in the main study could not be found in the present study: while SPI in the VSEs/SMEs was found a trend there, this trend could not be found in the papers from the study dataset.

C. RQ 3: Addressed Topics in Regions

In this section, we address our third research question and analyze which topics are researched in which regions and what the actual contributions are. That is, with this research question, we aim to analyze how SPI manifests in different regions around the globe. In order to generate a classification schema that helps structuring the respective contributions, we summarized each paper in 2-3 sentences, which were used to generate a word cloud. Figure 5 shows the result.

Fig. 5. Word cloud (filtered, threshold ≥ 5 mentions) generated from the paper summaries.

As already hypothesized in the main study, we expected SPI in the GSE context to emphasize the cultural and managerial aspects rather than technical issues (an observation, which is also supported by Ebert et al. [9]). The word cloud[2] in Fig. 5 confirms the initial observation, and this word cloud was used to eventually conclude the classification schema applied to answer the third research question. Using the word cloud, we reviewed the paper summaries and concluded the following categories:

Culture: Papers that lay their focus on cultural aspects, such as models or cultural differences.

Management: Papers dealing with all sorts of management and measurement.

Standard SPI: Papers focusing on discussing (quasi-) standardized SPI models.

Agile: Papers that deal with adopting agile to the global scale.

[2]To generate the word clouds, we used the online tool TagCrowd, which is available from: http://tagcrowd.com.

TABLE I
OVERVIEW OF THE REVIEWED PAPERS, THEIR THEMATIC CLASSIFICATION, AND THE RESPECTIVE REGIONS.

Ref.	Culture	Management	Standard SPI	Agile	Success Factors	Region	Rigor	Relevance
[7]		✓				US	2.5	4
[8]	✶				✓	US, Germany	2	4
[23]		✓				Germany	1	0
[24]	✓					China	1.5	0
[25]	✓				✶	Bangladesh	2	4
[26]	✓				✶	Thailand	1.5	4
[27]				✓		Norway	2.5	4
[28]		✓				*NA*	0	0
[29]			✓			Thailand	2	4
[30]		✓	✶			Italy	2	4
[31]		✓				*NA*	1	2
[32]					✓	US	0.5	3
[33]					✓	Vietnam	2.5	4
[34]			✓			US, Germany	1.5	4
[35]	✓		✶			Denmark	2.5	4
[36]		✓				*NA*	0	0
[37]		✓				UK	1	4
[38]	✓					Greece, Denmark, Finnland, UK	2	4
[39]			✶	✶	✓	*NA*	3	4
[40]	✓		✶			Taiwan	2	4
[41]		✓				US, Canada, Brazil, UK, Iceland, Denmark, Germany, Netherlands, India, Ireland, Japan	3	4
[42]					✓	Vietnam	3	4
[43]		✓				Belgium	0.5	2
[44]	✓					Greece, Denmark, Finnland, UK	2	4
[45]				✓		Finnland	3	4
[46]					✓	UK	2	4
[47]		✓				Pakistan	0.5	2
[48]		✓				US	2	4
[49]				✓		Norway	0.5	4
[50]				✓		Canada	0.5	2
	7	11	2	4	6			

NA: Region not available; ✶: Context in which the main topic is discussed

Success Factors: Papers that address SPI success factors and barriers.

The result of the categorization is summarized in Table I. The table shows the assignments of the papers to the respective focus type, but also (if applicable) some context information. For instance, in [39], authors put emphasis on success factors, but discuss the success factors (and respective barriers) in the context of adapting standard SPI models by utilizing agile practices. Table I provides the big picture, which we refine in the following.

Fig. 6. Word cloud summarizing the regions of reported SPI from Table I.

Figure 6 visualizes the different countries from which the analyzed SPI endeavors were reported. The figure shows the "SPI hot spots": Northern America, Europe, and Asia. Relating the countries to Table I, we also see certain trends. In the following, we use the three major regions found to discuss (selected) details.

1) Emerging Countries in Asia: Four of the seven papers addressing culture deal with establishing SPI programs in Asia [24]–[26], [40]. A major concern here is how established SPI models (e.g., Shih and Huang [40]) can be adopted to the Asian region, and, in this context, culture-related barriers and success factors are investigated. Phongpaibul and Boehm [26] investigate cultural differences and come to a similar conclusion. They study whether and how US-like SPI programs can be adapted in Thailand and conclude that such SPI programs cannot applied to Thailand in their "pure form" and that the cultural differences bear success factors as well as risks. Culture is also studied in the context of the "developed countries", e.g., two papers [38], [44] analyze the impact of culture on SPI in the European context by applying the so-called C.HI.D.DI typology to help companies identifying the national culture and to select an appropriate SPI approach.

As mentioned before, SPI barriers and success factors play an important role. In the Asian region, barriers and success factors are mainly studied in the context of emerging countries that want to enter the global market. For instance, Babar and Niazi [33] and Niazi et al. [42] study barriers and success factors in Vietnam and compare their findings with reference studies conducted in Australia. Selected findings from [42] comprise that there are similarities and differences in Vietnam and Australia. In conclusion, authors give some recommendations (shortened):

- Management needs to be committed to providing training for project management activities.
- Project planning is an essential practice in organizations and should be addressed.
- Management should establish project monitoring and control practices in their organizations.
- Staff members should be encouraged to take project management certification.

Comparing the results from interviewing managers and developers, among others, they found the most remarkable similarities are *lack of support* and *lack of resources for SPI projects*, which are addressed by the aforementioned recommendations.

2) Developed Countries: The "developed and mature" regions, i.e., Northern America and Europe, put a focus on improving the management of distributed projects and the problems coming along with implementing SPI programs in multinational companies. For instance, Paulish and Carleton [8] report experiences of SPI assessments at Siemens referring to SPI activities implemented in US and Germany. They found different barriers, such as staff turnover (e.g., downsizing or outsourcing, which is considered a bigger problem in US than in Germany), lacking dedicated resources and part-time staff allocation, management support, and the work prioritization, i.e., product delivery over SPI. Eventually, they conclude that there are differences in culture affecting SPI implementation and acceptance. Moreover, one and the same method was introduced, deployed, and trained in the US and Germany, but with completely different effects.

Umarji and Seaman [7] report an interview study in which a large company's employees were interviewed about the use of metrics. The studied company implemented an SPI program to harmonize metrics (which was necessary due to acquisition of new companies and a silo-infrastructure) and thus a number of metrics should be reported. Among other things, the study reveals that some people are keen on doing the metrics, while others implement a gaming strategy to "fake" metrics. As reasons, the study names, e.g., suppressing information (tuning reports), scripting (mimic reporting), and entering false data (to appear compliant). After the company's expansions, using such strategies, people create an illusion of compliance by, at the same time, working against a standardization program to keep the established organizational culture and to fight against a perceived remote controlling (see also [38], [44]).

3) SPI, Agile, and Scandinavia: Especially in Scandinavia, much effort is put on the agile transformation. This transformation is for instance studied by Korhonen [45], who found in his longitudinal study that agile methods improved collaboration communication in teams; also across different sites. However, this study did not follow a "formal" SPI approach, but shows companies putting effort in scaling agile methods to the global scale. Nevertheless, in particular this study underlines an issue also discussed in [51], namely that companies have increasing interest into deploying agile methods, but often face problems when it comes to selecting and combining practices properly.

Similarly, Hannay and Benestad [27] report a large case study in which agile methods were applied to a large project that comprises 11 virtual Scrum teams. Their detailed analysis of the setup of the virtual teams reveals critical success factors

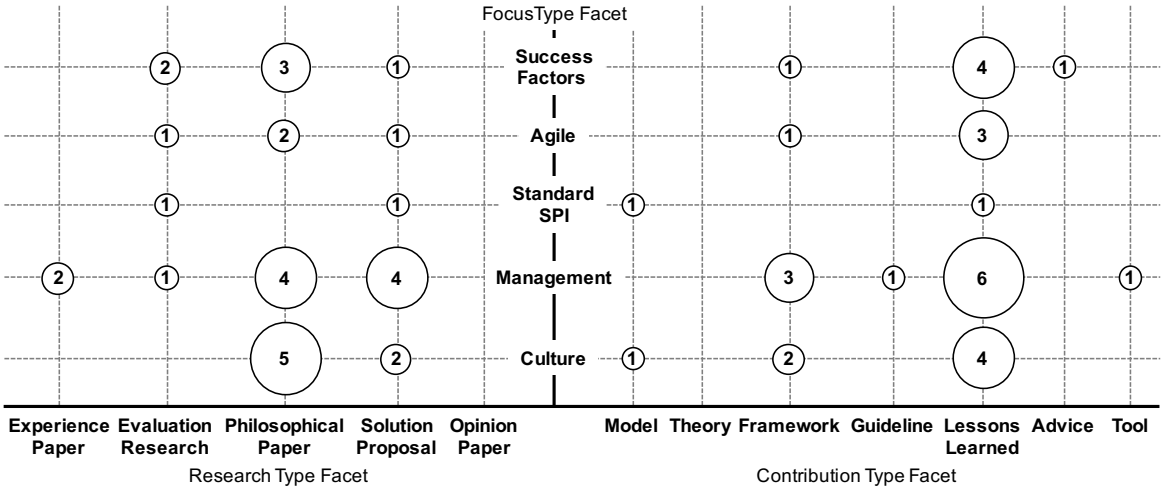

Fig. 7. Systematic map illustrating the research-, contribution-, and focus type facets in the study data.

that can help steering such an SPI endeavor. Furthermore, a major outcome is a collection potential of threats to productivity, which authors summarized in 10 problem areas:

1) Restraints on collaboration due to contracts, ownership and culture
2) Architectural and tech. qualities are given low priority
3) Conflicts between organizational control and flexibility
4) Volatile and late requirements from external parties
5) Lack of a shared vision for the end product
6) Limited dissemination of functional knowledge
7) Excessive dependencies within the system
8) Overloading of key personnel
9) Difficulties in maintaining technical environments
10) Difficulties in coordinating test/deployment with external parties

These factors show that SPI in the GSE context actually faces the same problems as SPI in the "classic" sense (e.g., goal conflicts, skilled personnel, and high work loads; cf. Sect. IV-C1). However, considering the other previously discussed papers, the central role of collaboration and communication across different sites becomes obvious.

D. Discussion & Threats to Validity

The study at hand aims at providing a big picture on how SPI treats the field of GSE. However, the present study has some limitations: Since the present study is a scoped study grounded in the dataset of a more comprehensive (yet less detailed) mapping study [3], the findings presented are significantly influenced by the research design of the main study. In particular, the present study does not analyze the field of GSE regarding how SPI is represented, rather than the other way round, i.e., what role does GSE play in the field of SPI. In this section, we discuss our findings as follows: In Sect. IV-D1, we discuss the findings obtained from the present study, and we add a broader discussion also considering related studies in Sect. IV-D2. Finally, in Sect. IV-D3, we discuss the threats to validity.

1) Discussion of the Obtained Results: Taking the five focal points defined in Sect. IV-C that are addressed by the analyzed studies, we first create the systematic map in Fig. 7 in which we relate the focus type facets with the research- and contribution type facets. The figure shows the trend observed in Fig. 2 and adds the focal points as new dimension.

The majority of the analyzed papers is, again, classified as *philosophical paper*, and most papers report *lessons learned*. Considering GSE from the perspective of SPI, the studied papers show a clear focus on management-related topics (11 out of 30), such as project management, knowledge management, quality management, or risk management, followed by studies considering culture (7 out of 30), and SPI barriers and success factors (6 out of 30). Adding the regions, culture and success factors are mostly discussed in the context of emerging countries, as there is a need, e.g., to analyze how companies in such countries can enter the global business and how companies in those countries can work towards harmonizing their software development (culture) with companies searching for outsourcing opportunities. Scaling agile to GSE (4 out of 30 papers) is a topic mostly addressed in the Scandinavian region, whereas the data also shows that respective initiatives do not use large standard approaches, such as CMMI (as for instance seen in [27], [45]).

Figure 7 also confirms the trend found in [2], [3] by showing the absence of theories and the low number of evaluation research compared to a high number of solution proposals and philosophical papers. Yet, two particular trends found in the main study could not be explicitly seen in the analyzed data subset: First, in the main study, a considerable share of papers is devoted to SPI efforts in the context of very small entities and small-to-medium-sized enterprises. In the present study, the majority of the reports emerges from large-scale companies. However, we have to admit that several interview

studies, especially those conducted in Asia, give insufficient demographic information, such that we lack information about the size of the companies interviewed. The second clear trend in the main study is the work towards adopting agile principles to SPI. In the present study, we only find four papers explicitly addressing this topic, even though 25 papers are published after 2001 (publication of the Agile Manifesto). Compared to the study conducted by Ebert et al. [9], both observations are not in line with the retrospective analysis of the publication body of the GSE community thus motivating further research. Nevertheless, the reported research is of certain relevance to industry as the rating according to the rigor-relevance model in Fig. 3 and Table I also shows.

2) Discussion of Related Studies from GSE: As the present study takes a "special" perspective, namely how is GSE treated from the perspective of (pure) SPI, we also have to discuss this setting the other way round. In Ebert et al. [9], authors analyze the publication pool of 10 years *IEEE International Conference on Global Software Engineering* (ICGSE). Their study names *Project Management*, *Collaboration and Team*, and *Process and Organization* to be the "Top 3" topics addressed by the ICGSE community. Especially the topic *Process and Organization*, inter alia, covers SPI-related research, and lists for instance the paper [33] from the present study's result set. Furthermore, the implementation of continuous improvement is addressed, e.g., by Laredo and Ranjan [52], as well as scaling agile for GSE (e.g., Cristal et al. [53]). Another aspect found in [9] is the management of (virtual) teams in the GSE context, as for instance discussed by Beecham et al. [54]. Looking at the GSE-centered studies, the result set analyzed in the present paper has some overlap regarding the included papers as well as in the focal points found. Therefore, although discussing GSE from a different angle, our findings can be considered a contribution to both, the body of knowledge on SPI and also to the body of knowledge on GSE (as for instance started/presented with a broader scope in [55], [56]).

3) Threats to Validity: In the following, we evaluate our findings and critically review our study regarding the threats to validity. As a literature study, this study suffers from potential incompleteness of the search results and a general publication bias, i.e., positive results are more likely published than failed attempts. Beyond this general threat to validity, we have to particularly discuss the internal and external validity.

a) Internal Validity: The internal validity of the study could be biased by personal ratings of the participating researchers. To address this risk, we continued and refined our study [2], [3], which follows a proven procedure that utilizes different tools and researcher triangulation to support dataset cleaning, study selection, and classification. The internal validity is also affected by the limited data collection, in particular, no new data was collected, and data analyzed in the present study is derived from the main study that serves as an umbrella. Calling in extra researchers to analyze and/or confirm decisions therefore further increases internal validity.

b) External Validity: The external validity is threatened by missing knowledge about the generalizability of the results. Furthermore, the present study "inherits" several limitations regarding the external validity by relying on the main study's raw data only. Consequently, the present study also inherits the main study's scope thus having certain limitations regarding the generalizability. However, by calling in extra researchers, revisiting the original categorizations, conducting extra quality assurance, and discussing further studies that address similar topics from a different angle, we improve the external validity. Nevertheless, to increase the external validity, further independently conducted studies are required to confirm our findings. With the study at hand, we lay the foundation for such future research.

V. Conclusion and Future Work

The paper at hand provides a scoped study and an in-depth analysis of how GSE is addressed by the SPI "core" community. The study is based on a data subset obtained from a comprehensive systematic mapping study [2], [3], and provides an in-depth analysis of the papers from this subset. To conduct the data analysis, we relied on three (quasi-)standard classification schemas and models to evaluate the paper pool's maturity, contribution, rigor, and relevance. Furthermore, in order to provide specific insights, we developed a study-specific schema utilizing the systematic review instrument.

Our findings show that the major trend observed in the main study continues, i.e., SPI in the context of GSE is devoted to developing custom and/or new SPI approaches for specific domains and, furthermore, a considerable share of papers reports on lessons learned in applying SPI to industry. Key to the discussion of SPI in GSE are barriers and success factors to help implementing SPI in different regions around the globe. Hence, different to the main study, the investigated papers put even stronger emphasis on cultural and managerial topics, which is in line with further (external) studies, such as [9]. Notably the study-specific classification schema reveals three major regions from which SPI research and experience is reported:

In the regions of Northern America and Europe, i.e., the "developed countries", research and experience deal with managerial aspects and culture within large multi-national companies. Remarkable findings include that in such settings culture also plays an important role, as centralized SPI initiatives deploying one solution to all sites encounter a high risk of failure—culture matters. Within the European region, in Scandinavia, managing the agile transformation including scaling agile to GSE is considered highly important. Analyzed papers from this region show a certain reluctance to following large standard approaches to organize SPI (e.g., CMMI), and prefer a more pragmatic approach (which is also in line with the main study that comprises a significant share of papers (almost 50%) utilizing non-standardized SPI approaches).

Being a relevant target for different sourcing activities, SPI has become relevant for emerging countries as well. Results obtained in this study show some effort spent on SPI in Asia, and the majority of the studies is devoted to culture. Notably, culture is analyzed from the perspective of differences and

similarities, i.e., what is required to be aware of when conducting SPI to prepare Asian companies for the global market. Key findings include differences, but also reveal similarities of which most are concerned with resources, awareness, skills and qualification, and openness towards SPI.

Although our study has certain limitations, those findings add to the fact that SPI is risky and thus requires management commitment and support, sufficient resources, and skilled personnel.

A. Limitations and Impact

Our study is limited by the context set by the main study [2], [3], yet showed some overlap and similar trends as obtained in other independently conducted studies, such as [9]. In total, only 30 papers were selected for analysis and, therefore, this study cannot claim to have delivered a generalizable set of conclusions. Major limitations are that the Southern American and the Australian continents, and the Arabian region are not significantly represented in the study, and that papers from Africa are not included at all. Therefore, we could only analyze papers from three regions thus missing knowledge about more or different trends applied in other regions. Furthermore, due to the small result set, we have no knowledge regarding other trends and approaches, even in those regions studied so far.

Nevertheless, the paper provides some valuable insights for researchers and practitioners. By collecting and structuring the analyzed papers, we provided starting points, e.g., what to consider when it comes to start SPI in Asia. The result set presented here can thus serve as a baseline to obtain valuable insights, which are of high relevance to industry (cf. Sect. IV-A). Furthermore, we worked out the white spots on the global map of which we have not found information as well as the "under-researched" fields of SPI thus motivating further research.

B. Future Work

As part of a more comprehensive work, this study motivates further activities. First, the more detailed findings obtained in the present study need to be re-integrated with the main study to improve the main study's data quality. This will happen in the course of the planned continuous updates of the main study that aim at creating a big picture of SPI in general. Further future work comprises extra (independently conducted) studies to complete, refine, and confirm the findings obtained in the study at hand. Of special interest in this context is obtaining more data from those regions not yet covered by the present study, i.e., information regarding SPI in a GSE context for the regions Southern America, Australia, Arabia, and Africa. Furthermore, more effort needs to be spent on studying the particular SPI approaches taken. For instance, while the publications analyzed in this paper show Asia taking standard models like CMMI as a reference, we see Scandinavia already working towards the "beyond agile" era, which is even stronger shaped by Lean software and product development approaches. Therefore, we need to study the different SPI approaches, as we have to expect an increasing diversification rather than a consolidation.

References

[1] Humphrey, W. S., *Managing the Software Process*. Addison Wesley, 1989.

[2] M. Kuhrmann, C. Konopka, P. Nellemann, P. Diebold, and J. Münch, "Software process improvement: Where is the evidence," in *Proceedings of the International Conference on Software and System Process*, ser. ICSSP. ACM, 2015, pp. 107–116.

[3] M. Kuhrmann, P. Diebold, and J. Münch, "Software process improvement: A systematic mapping study on the state of the art," *PeerJ Computer Science*, (in revision) 2016.

[4] M. Staples, M. Niazi, R. Jeffery, A. Abrahams, P. Byatt, and R. Murphy, "An exploratory study of why organizations do not adopt cmmi," *Journal of Systems and Software*, vol. 80, no. 6, pp. 883–895, 2007.

[5] R. V. Horvat, I. Rozman, and J. Györkös, "Managing the complexity of spi in small companies," *Software Process: Improvement and Practice*, vol. 5, no. 1, pp. 45–54, 2000.

[6] D. L. Parnas and P. C. Clements, "A rational design process: How and why to fake it," *IEEE Transactions on Software Engineering*, vol. 12, no. 2, pp. 1–10, Jan. 1986.

[7] M. Umarji and C. Seaman, "Why do programmers avoid metrics?" in *Proceedings of the International Symposium on Empirical Software Engineering and Measurement*, ser. ESEM. ACM, 2008, pp. 129–138.

[8] D. Paulish and A. Carleton, "Case studies of software-process-improvement measurement," *IEEE Computer*, vol. 27, no. 9, pp. 50–57, 1994.

[9] C. Ebert, M. Kuhrmann, and R. Prikladnicki, "Global software engineering: An industry perspective," *IEEE Software*, vol. 33, no. 1, pp. 105–108, Jan 2016.

[10] L. F. S. Monteiro and K. M. de Oliveira, "Defining a catalog of indicators to support process performance analysis," *Journal of Software Maintenance and Evolution: Research and Practice*, vol. 23, no. 6, pp. 395–422, 2011.

[11] S. Bayona-Oré, J. Calvo-Manzano, G. Cuevas, and T. San-Feliu, "Critical success factors taxonomy for software process deployment," *Software Quality Journal*, vol. 22, no. 1, pp. 21–48, 2014.

[12] T. Dybå, "An instrument for measuring the key factors of success in software process improvement," *Empirical Software Engineering*, vol. 5, no. 4, pp. 357–390, 2000.

[13] Y. Y. L. Helgesson, M. Höst, and K. Weyns, "A review of methods for evaluation of maturity models for process improvement," *Journal of Software: Evolution and Process*, vol. 24, no. 4, pp. 436–454, 2012.

[14] M. Hull, P. Taylor, J. Hanna, and R. Millar, "Software development processes - an assessment," *Information and Software Technology*, vol. 44, no. 1, pp. 1–12, 2002.

[15] K. El-Emam and D. R. Goldenson, "An empirical review of software process assessments." *Advances in Computers*, vol. 53, pp. 319–423, 2000.

[16] M. Staples and M. Niazi, "Systematic review of organizational motivations for adopting cmm-based spi," *Information and Software Technology*, vol. 50, no. 7/8, pp. 605–620, 2008.

[17] S. D. Müller, L. Mathiassen, and H. H. Balshøj, "Software Process Improvement as organizational change: A metaphorical analysis of the literature," *Journal of Systems and Software*, vol. 83, no. 11, pp. 2128–2146, Nov. 2010.

[18] K. Petersen, R. Feldt, S. Mujtaba, and M. Mattson, "Systematic mapping studies in software engineering," in *International Conference on Evaluation & Assessment in Software Engineering*, ser. EASE. ACM, 2008, pp. 68–77.

[19] B. Kitchenham and S. Charters, "Guidelines for performing systematic literature reviews in software engineering," Keele University, Tech. Rep. EBSE-2007-01, 2007.

[20] N. Paternoster, C. Giardino, M. Unterkalmsteiner, T. Gorschek, and P. Abrahamsson, "Software development in startup companies: A systematic mapping study," *Information and Software Technology*, vol. 56, no. 10, pp. 1200 – 1218, 2014.

[21] M. Ivarsson and T. Gorschek, "A method for evaluating rigor and industrial relevance of technology evaluations," *Empirical Software Engineering*, vol. 16, no. 3, pp. 365–395, June 2011.

[22] R. Wieringa, N. Maiden, N. Mead, and C. Rolland, "Requirements engineering paper classification and evaluation criteria: A proposal and a discussion," *Requirements Engineering*, vol. 11, no. 1, pp. 102–107, Dec. 2005.

[23] A. Averbakh, E. Knauss, and O. Liskin, "An experience base with rights management for global software engineering," in *International Conference on Knowledge Management and Knowledge Technologies*, ser. i-KNOW. ACM, 2011, pp. 10:1–10:8.

[24] W. Ma, L. Liu, W. Feng, Y. Shan, and F. Peng, "Analyzing project risks within a cultural and organizational setting," in *Workshop on Leadership and Management in Software Architecture*, ser. LMSA. IEEE, 2009, pp. 6–14.

[25] B. Wong and S. Hasan, "Cultural influences and differences in software process improvement programs," in *Proceedings of the International Workshop on Software Quality*, ser. WoSQ. ACM, 2008, pp. 3–10.

[26] M. Phongpaibul and B. Boehm, "Improving quality through software process improvement in thailand: Initial analysis," in *Proceedings of the Workshop on Software Quality*, ser. WoSQ. ACM, 2005, pp. 1–6.

[27] J. E. Hannay and H. C. Benestad, "Perceived productivity threats in large agile development projects," in *Proceedings of the International Symposium on Empirical Software Engineering and Measurement*, ser. ESEM. ACM, 2010, pp. 15:1–15:10.

[28] J. L. Smith, S. A. Bohner, and D. S. McCrickard, "Project management for the 21st century: Supporting collaborative design through risk analysis," in *Proceedings of the 43rd Annual Southeast Regional Conference - Volume 2*, ser. ACM-SE. ACM, 2005, pp. 300–305.

[29] P. Mongkolnam, U. Silparcha, N. Waraporn, and V. Vanijja, "A push for software process improvement in thailand," in *Asia-Pacific Software Engineering Conference*, ser. APSEC. IEEE, 2009, pp. 475–481.

[30] E. Bellini and C. lo Storto, "CMM implementation and organizational learning: Findings from a case study analysis," in *Proceedings of PICMET: Technology Management for the Global Future*, ser. PICMET, vol. 3. IEEE, 2006, pp. 1256–1271.

[31] X. Chen, P. Sorenson, and J. Willson, "Continuous SPA: Continuous assessing and monitoring software process," in *IEEE Congress on Services*. IEEE, 2007, pp. 153–158.

[32] D. Weiss, D. Bennett, J. Payseur, P. Tendick, and P. Zhang, "Goal-oriented software assessment," in *International Conference on Software Engineering*, ser. ICSE. IEEE, 2002, pp. 221–231.

[33] M. Babar and M. Niazi, "Implementing software process improvement initiatives: An analysis of vietnamese practitioners' views," in *International Conference on Global Software Engineering*, ser. ICGSE. IEEE, 2008, pp. 67–76.

[34] N. Ramasubbu, M. Krishnan, and P. Kompalli, "Leveraging global resources: a process maturity framework for managing distributed development," *IEEE Software*, vol. 22, no. 3, pp. 80–86, May 2005.

[35] S. Muller, P. Kraemmergaard, and L. Mathiassen, "Managing cultural variation in software process improvement: A comparison of methods for subculture assessment," *IEEE Transactions on Engineering Management*, vol. 56, no. 4, pp. 584–599, Nov 2009.

[36] C. Boldyreff, J. Newman, and J. Taramaa, "Managing process improvement in virtual software corporations," in *Proceedings of the 5th Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*. IEEE, 1996, pp. 142–147.

[37] Z. Haag, R. Foley, and J. Newman, "Software process improvement in geographically distributed software engineering: an initial evaluation," in *Proceedings of the 23rd EUROMICRO Conference*. IEEE, 1997, pp. 134–141.

[38] K. Siakas, "What has culture to do with SPI?" in *Proceedings of the 28th EUROMICRO Conference*. IEEE, 2002, pp. 376–381.

[39] T. Galinac, "Empirical evaluation of selected best practices in implementation of software process improvement," *Information and Software Technology*, vol. 51, no. 9, pp. 1351–1364, Sep. 2009.

[40] C.-C. Shih and S.-J. Huang, "Exploring the relationship between organizational culture and software process improvement deployment," *Information and Management*, vol. 47, no. 5-6, pp. 271–281, Aug. 2010.

[41] I. van de Weerd, S. Brinkkemper, and J. Versendaal, "Incremental method evolution in global software product management: A retrospective case study," *Information and Software Technology*, vol. 52, no. 7, pp. 720–732, Jul. 2010.

[42] M. Niazi, M. A. Babar, and J. M. Verner, "Software process improvement barriers: A cross-cultural comparison," *Information and Software Technology*, vol. 52, no. 11, pp. 1204–1216, Nov. 2010.

[43] C. Ebert, "Technical controlling and software process improvement," *Journal of Systems and Software*, vol. 46, no. 1, pp. 25–39, Apr. 1999.

[44] K. V. Siakas and E. Georgiadou, "Empirical measurement of the effects of cultural diversity on software quality management," *Software Quality Journal*, vol. 10, no. 2, pp. 169–180, Sep. 2002.

[45] K. Korhonen, "Evaluating the impact of an agile transformation: A longitudinal case study in a distributed context," *Software Quality Journal*, vol. 21, no. 4, pp. 599–624, Dec. 2013.

[46] T. Hall, A. Rainer, and N. Baddoo, "Implementing software process improvement: an empirical study," *Software Process: Improvement and Practice*, vol. 7, no. 1, pp. 3–15, 2002.

[47] M. Faizan, S. Ulhaq, and M. Khan, "Defect prevention and process improvement methodology for outsourced software projects," *Middle-East Journal of Scientific Research*, vol. 19, no. 5, pp. 674–682, 2014.

[48] N. Ramasubbu, "Governing software process improvementsin globally distributed product development," *IEEE Transactions on Software Engineering*, vol. 40, no. 3, pp. 235–250, March 2014.

[49] E. Papatheocharous and A. S. Andreou, "Evidence of agile adoption in software organizations: An empirical survey," in *Systems, Software and Services Process Improvement*, ser. Communications in Computer and Information Science. Berlin Heidelberg: Springer, 2013, vol. 364, pp. 237–246.

[50] P. Kruchten, "Contextualizing agile software development," *Journal of Software: Evolution and Process*, vol. 25, no. 4, pp. 351–361, 2013.

[51] G. Theocharis, M. Kuhrmann, J. Münch, and P. Diebold, "Is water-scrum-fall reality? on the use of agile and traditional development practices," in *Proceedings of the International Conference on Product-Focused Software Process Improvement*, ser. Lecture Notes in Computer Science, vol. 9459. Berlin Heidelberg: Springer, 2015, pp. 149–166.

[52] J. Laredo and R. Ranjan, "Continuous improvement through iterative development in a multi-geography," in *International Conference on Global Software Engineering*, ser. ICGSE. IEEE, Aug 2008, pp. 232–236.

[53] M. Cristal, D. Wildt, and R. Prikladnicki, "Usage of Srum practices within a global company," in *International Conference on Global Software Engineering*, ser. ICGSE. IEEE, 2008, pp. 222–226.

[54] S. Beecham, J. Noll, I. Richardson, and N. Ali, "Crafting a global teaming model for architectural knowledge," in *International Conference on Global Software Engineering*, ser. ICGSE. IEEE, 2010, pp. 55–63.

[55] D. Šmite, C. Wohlin, T. Gorschek, and R. Feldt, "Empirical evidence in global software engineering: A systematic review," *Empirical Software Engineering*, vol. 15, no. 1, pp. 91–118, Feb. 2010.

[56] D. Šmite and C. Wohlin, "A whisper of evidence in global software engineering," *IEEE Software*, vol. 28, no. 4, pp. 15–18, Jul. 2011.