Empirical research methodologies and studies in Requirements Engineering: How far did we come?

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ABSTRACT

Since the inception of the RE conference series (1992), both researchers and practitioners in the RE community have acknowledged the significance of empirical evaluation as an instrument to gain knowledge about various aspects of RE phenomena and the validity of our research results. A significant number of empirical studies have been conducted in the search for knowledge about RE problems as well as evidence of successful and less successful application of proposed solutions. This editorial presents the progress empirical RE research has made since 1992. Based on a search in the Scopus digital library, we report from an analysis of peer-reviewed systematic literature reviews and mapping studies to showcase major areas of RE research that use methods from the Empirical Software Engineering paradigm. We summarize prior empirical research in RE and introduce the contributors to this special issue on empirical research methodologies and studies in RE.

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1. Introduction

Requirements Engineering (RE) has become a well-established discipline where a wide range of approaches, techniques and tools have been proposed. Systematic attempts to evaluate and compare the usefulness, effectiveness and usability of such proposals resulted in a growing attention to methods for empirical assessment. Empirical Software Engineering (ESE) aims at applying the empirical research methodologies to the software engineering field. It aims at studying and proposing qualitative and quantitative methods to collect and analyze evidence that helps evaluating software engineering approaches, techniques and tools. Experiments, surveys, case studies, action research studies, hence, become indispensable and valuable methods to verify that the proposed research ideas and results conform with the reality of software engineering; they become indispensable in assessing their value, cost and benefits in particular operational contexts. The objective of this Special Issue is to increase the awareness of the value of and the need for cross-fertilization of ESE methods and RE. More specifically, we intend to foster a discussion among researchers and practitioners

on what are the better ways (1) to strengthen the methodological base of RE research and (2) to leverage empirical evaluation approaches to explore and consolidate the multidisciplinary nature of industry-relevant RE research.

Historically, a workshop series focused specifically on empirical methods in RE was created in 2011 in the form of the International Workshop on Empirical Requirements Engineering (EmpiRE), and one article from its 2012 edition is published in this special issue. The EmpiRE workshop series builds upon an earlier workshop series on Comparative Evaluation in Requirements Engineering (CERE) (2003–2007), and which aimed at setting up systematic empirical evaluation practices that serve the purpose of comparing RE methods, processes and technologies (Gervasi et al., 2004). The workshop triggered a number of important conversations on pragmatic topics that directly responded to the urgent need for formulating criteria that make comparison of the effectiveness of various RE research outcomes possible. Most notably, the topics included (1) what evaluation criteria empirical RE researchers should consider for use when comparing RE methods, processes and technologies (e.g. CERE'06 http://www.di.unipi.it/CERE06/program.html), and (2) what criteria to use to evaluate the research output of such comparative efforts (e.g. Wieringa et al., 2005; Easterbrook, 2007a). Perhaps, the most lasting contribution of the CERE workshop series is the

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classification of RE research papers (Wieringa et al., 2005, 2006; Wieringa, 2005; Easterbrook, 2007a,b) which to these day is used by the RE community to guide the work of the PC members when reviewing papers submitted to the annual RE and REFSQ conferences.

This editorial not only introduces the special issue papers, but also is set out to provide a reflection on past empirical research in RE and challenges lying ahead. In particular, it is important for us to understand what empirical RE evidence has been accumulated over time and on which RE sub-topics (e.g. elicitation methods, modeling techniques) or application domains. In the RE field, the first empirical study has been published in 1983 (Davis, 1983), nine years before the initiation of the RE conference series. Given the importance of empirical research and evaluation, it is perhaps surprising that relatively little effort has been done toward the cross-fertilization of ESE and RE in a systematic way.

The rest of this editorial is organized as follows: In Section 2 we provide background on the possible factors that fueled the increased awareness of empirical RE in the past few years. In Section 3, we first describe the growth of empirical RE publications, which is based on a search for empirical RE publications in the Scopus digital library. Also, we summarize observations from published mapping studies and systematic literature reviews in RE available in Scopus. We examined the topics covered, the primary studies being used in the process of evaluating evidence, the theories being used in those studies, and the way generalization questions were treated. We summarize the research progress, discuss some challenges for the future, and finally present the papers making up this Special Issue.

2. The increasing awareness of ESE principles in RE research

In the RE community there is a consensus that comparative evaluation of RE research efforts play a crucial role in (1) the growth of RE as a scientific discipline and (2) technology transfer. Much empirical publication output was produced by the community and a broad variety of empirical research methods from the evidence-based software engineering paradigm (Kitchenham et al., 2004) have been used and reflected upon: systematic reviews, experiments, case studies, focus group studies, grounded theory studies, action research. The RE community seems to work really hard on identifying the appropriate research methodologies to study RE phenomena and the evaluation criteria suitable to judge RE research efforts and output (Gervasi et al., 2004; Wieringa et al., 2005). We outline below some of the main reasons for the growth of publications on empirical research in RE.

First, the software industry and the IT consulting sector in general are increasingly more aware of both the expenses associated with poor requirements and the importance of adopting or adapting good RE practices. Detailed market data analyses conducted over the years point to RE as the most expensive part of any systems delivery project, regardless of country or organizational settings. Similarly, research on critical success factors and productivity in software development has been advancing (e.g. Shaul and Tauber, 2013; Wagner and Ruhe, 2008), providing clear evidence of the quality of requirements as a factor that can make or break a project. This fuels the motivation of RE researchers to evaluate the extent to which their proposed techniques add value to businesses and help change the odds for project outcomes. To companies, this means getting more conscious about actively searching for practices that worked in other organizations and attempting to emulate these organizations' successes based on evaluation of existing evidence.

Second, the recent developments in large scale outsourcing worldwide highlight the need of explicitly specifying requirements very early in the systems delivery cycle as part of setting outsourcing contracts (Damian, 2007; Damian and Moitra, 2006; Daneva et al., 2013). Often, RE becomes a pre-project on its own that is priced separately and is aimed explicitly at 'getting requirements right'.

Third, research funding agencies in Europe and North America call increasingly for industry-university collaboration project proposals on mulidisciplinary research in which RE plays an important role, e.g. in the development of systems in the domains of smart cities, internet of things, healthcare and online gaming. Project proposals are required to include plans for empirical evaluation of existing RE methods, processes and technologies for the purpose of understanding their possible fit to the problem to determine the requirements for systems in these application domains.

Forth, as the RE field has been maturing for the past two decades, the awareness of explicit and systematic documentation of empirical research designs has been growing, too. There is an agreement in the RE community today that the more explicitly a research design is described, the easier it is for the readers of empirical RE papers to evaluate the generalizability of the research being published, e.g. the extent to which readers might expect to observe published results in other similar but different settings.

3. Review of past empirical research in RE

3.1. Growth of empirical RE publications and geographic distribution

Fig. 1 illustrates the growth of empirical RE publications based on a search of literature sources available in the Scopus digital library.[1] The search was done on May 13, 2014 and yielded 2218 research papers published between January 1, 1983 and December 31, 2013. For the purpose of getting indicative information on the points discussed in this editorial as well as to provide examples, we chose to use Scopus because it tracks a large number of journals and conferences in computer science and information systems research, while giving us the advantage in facilitating a single search query access items from a broad variety of publishers, unlike Springer when using SpringerLink, or Elsevier when using ScienceDirect.

This search resulted in 628 journal papers, 19 book chapters, and 1590 conference papers. Fig. 1 shows the growth of published empirical RE studies between 1983 and end of 2013.

Using the results of our search, we examined the distribution of these papers across the different countries. Fig. 2 presents the number of articles per country. We observe that while nearly 30% (773 out of 2218) of the papers originated in the United States, United Kingdom and Canada, the affiliations of the authors of empirical RE research publications are located in a total of 40 countries. Among the European countries, authors from Germany produced the highest number of empirical RE papers (232). The other European countries to which a high number of empirical RE authors affiliated while publishing empirical papers are Italy, Sweden, Austria and the Netherlands. Authors from these countries produced papers ranging in volume between 106 and 128, in each country. Outside North America and Europe, Brazil stands out as a country contributing a high number of empirical RE papers (95). We also observe that empirical RE research activity takes place in Asian countries,

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[1] We used the following search string: "requirements engineering" AND ("action research" OR "grounded theory" OR "focus group" OR (empirical AND (study OR evaluation OR assessment OR analysis)) OR "field study" OR "qualitative study" OR "empirical research method" OR "experiment" OR "experimental study").
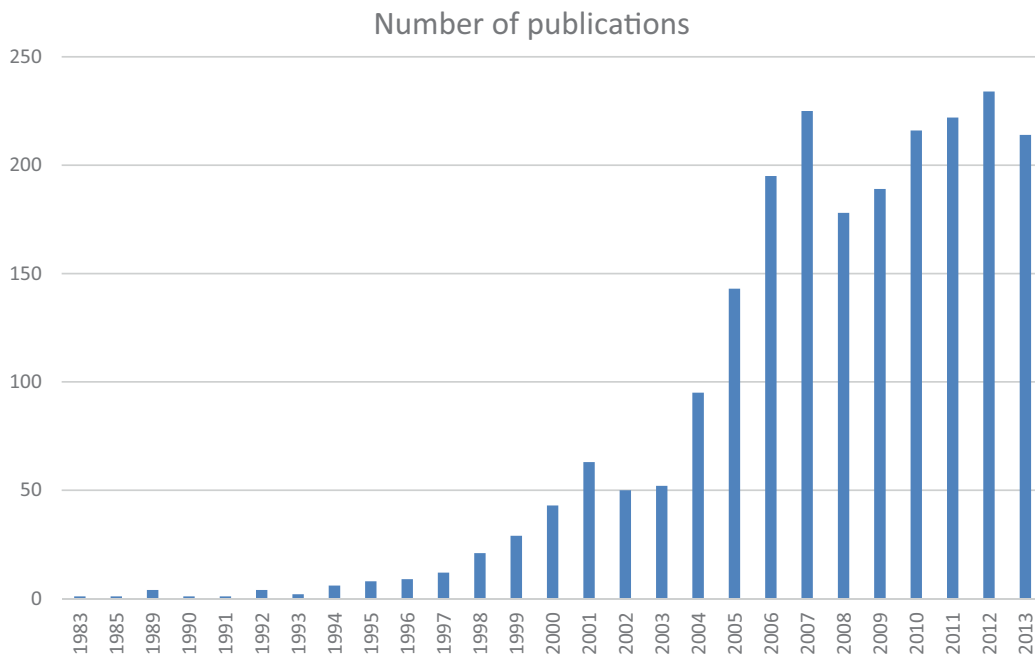
Number of publications

Fig. 1. Number of empirical RE study published since1983.

Table 1
Conferences.

Conference venue	Number of empirical RE publications
RE	198
REFSQ	55
ICSE	47
APSEC	28
EmpiRE	24
Euromicro SEAA	24
SAC	19
ESEM	17
HICCS	10
RCIS	8
COMSAC	8
EDOC	5

such as Saudi Arabia, Pakistan, South Korea and Taiwan. This is a very positive and encouraging development, given the fact that these countries are under-represented in the proceedings of the RE conference series (the premier meeting point of the RE community). We note that examples of empirical studies carried out by authors from these countries are published however in the Springer Requirements Engineering Journal (which is the premier journal in the RE community).

Furthermore, we looked at the venues, both conference series (Table 1) and journals (Table 2) where most research papers have been published. Table 1 confirms the intuitive assumption that the Requirements Engineering (RE) conference (requirements-enginnering.org) is the most popular conference outlet, followed by the REFSQ series (www.refsq.org). Clearly, this is unsurprising given the fact that both venues are regarded by the RE community as the premium destinations for RE research in general, and empirical RE, in particular. Furthermore, in its three editions (2011–2013) the EmpiRE[2] workshop published a total of 24 empirical RE studies.

Next, we observe that quite a few empirical RE papers are published in general SE conferences. The highest number of publications (see Table 1) are at the International Conference on Software Engineering (ICSE), at the Asia-Pacific Software Engineering Conference (APSEC), at Euromicro Conference on Software Engineering and Advanced Applications (SEAA), and at the ACM Symposium for Applied Computing (SAC). A large number of papers however are spread over an extremely large number of events, some of which are popular with communities, such as the Information Systems Research community, Human-Media Interaction, Cloud Computing, Wireless Sensors and Cellular Networks. Most of these events have published only one empirical RE study that is usually related to the central theme of the event.

In terms of journal papers, the Requirements Engineering Journal tops the list (see Table 2), followed by the journals that are well-known for publishing ESE research: the Journal of Information and Software Technology, the Transactions of Software Engineering, the Journal of Systems and Software, and IEEE Software. Next to these well-known ESE outlets, quite a few empirical RE papers (16) have been published in the European Journal of Information Systems. It is somewhat surprising that the Empirical Software Engineering Journal so far published 14 empirical RE papers, which ranks it lower in terms of popularity in the RE community compared to other journals.

Moreover, Table 2 indicates that empirical RE papers appeared in journals focused on specific SE sub-areas, e.g. the Software Quality Journal, the Journal of Software Practice and Experience, the Journal of Software Maintenance and Evolution, the International Journal on Software Tools for Technology Transfer, the Expert Systems Journal and the Journal of Expert Systems with Applications, which suggests that other SE communities also pay attention to empirical RE research. We also observe that a number of papers are spread over a wide range of journals, such as the Journal of Information and Management, Information Systems, the Journal of Enterprise Information Systems, the Journal of Human Computer Studies, the Health Informatics Journal and the Journal of Biomedical Informatics IEEE Intelligent Systems, Journal of Enterprise Transformation. This again, is again a hint that empirical RE research draws the attention of other communities beyond SE.

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[2] At the time of writing this editorial, the EmpiRE 2014 workshop is evaluating 18 other empirical RE studies.

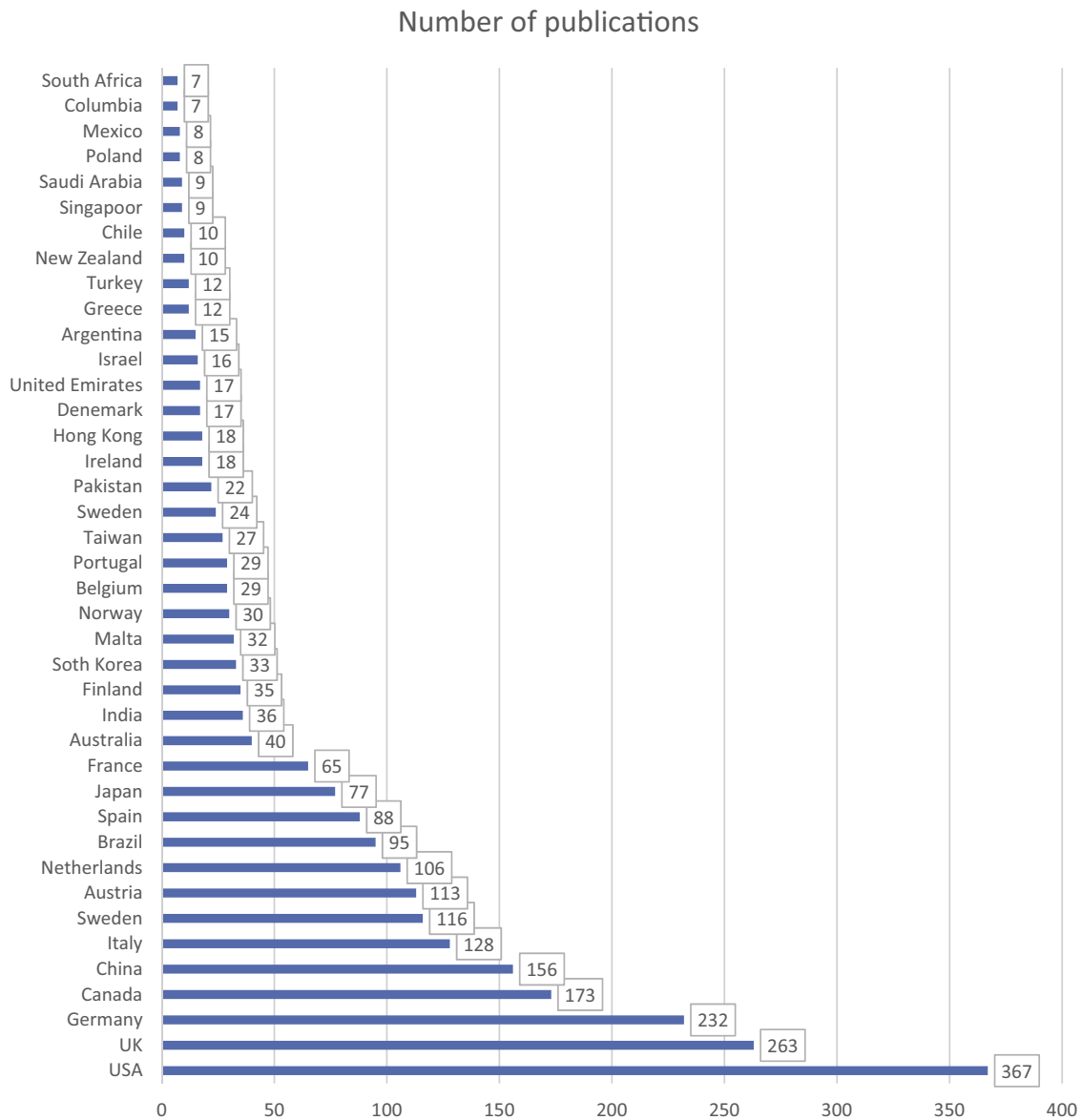## Number of publications

Fig. 2. Number of empirical RE study per country.

3.2. Topics and theoretical perspectives

This section narrows down the discussion to provide a snapshot of state-of-the art in evaluation of evidence produced in empirical RE studies as reported in systematic literature reviews and mapping studies in RE. Generally, one of the goals of a mapping studies and systematic reviews is to describe and evaluate state-of the-art research by using empirical evidence produced in primary studies (Kitchenham, 2006). As our goal is to indicate progress to date in empirical RE and use of methodologies, we considered reviewing these two kinds of reviews as a useful way to gain some indicative points for reflection on trends in the area. For the purpose of this editorial, we searched Scopus for these two kinds of reviews. Our search yielded 7 mapping studies and 49 systematic reviews. For each one, we checked (i) the topics covered, (ii) whether the study focuses on a RE artifact or a RE process, (iii) whether the study addresses a particular organizational/development context, and (iv) the application domain in which RE is applied. The next sub-section summarizes our observations.

3.2.1. Topics

Table 3 presents the topics that have been covered by mapping studies and systematic reviews published until May 2014. We found 38 distinctive topics. The topic with the highest number of studies are: requirements prioritization (4 studies), requirements specification (4 studies), security RE (4 studies) and creativity techniques for RE (3 studies). Table 3 also shows that the following topics are addressed in two studies each: user participation, stakeholder identification, goal-oriented RE, and requirements elicitation while all other topics were addressed in only one study each.

We found three SRs that dealt with RE artifacts: release planning models (Svahnberg et al., 2010), causes of requirements changes (Bano et al., 2012), and requirements errors (Walia and Carver, 2009). Regarding development contexts, we found the following: distributed (2 reviews – Ebling et al., 2009; Lai et al., 2012), model-driven RE (Loniewski et al., 2010), development of software product lines (Aves et al., 2010), and agile (Racheva et al., 2009). Concerning domains, five domains have been addressed so far: multi-agent systems in two reviews (Blanes et al., 2009a,b), self-adaptive

Table 2
Journals and magazines.

Journal/magazine	Number of empirical RE publications
Requirements Engineering Journal	66
Information and Software Technology	39
Transactions of Software Engineering	38
Journal of Systems and Software	36
IEEE Software	20
European Journal of Information Systems	16
Empirical Software Engineering Journal	14
Journal of Software Engineering and Knowledge Engineering	13
Communications in Computers & Information Science	11
Automated Software Engineering	10
IEICE transactions on Information & Systems	10
Journal of Universal Computer Science	8
Information Systems	8
IEEE Latin America Transactions	8
Journal of Universal Computer Science	8
ACM Transactions on Software Engineering and Methodology	7
International Journal on Human-Computer Studies	7
Software Practice and Experience	6
Journal of Software Maintenance	6
Software Maintenance and Evolution	6
Software Quality Journal	6
IET Journal of Software	5
Jisuanji Xuebao/Chinese Journal of Computers	5
Information Systems Journal	4
Information & Management	4
Journal of Computer Information Systems	4
Enterprise Information Systems	4
International Journal on Software Tools for Technology Transfer	4
Jisuanji Yanjiu yu Fazhan/Computer Research and Development	4
International Journal of Information System Modeling and Design	3
Information Systems and e-Business Management	3
Expert Systems with Applications	3
Knowledge-Based Systems	3
Journal of Industrial Management Data and Systems	3
Applied Soft Computing Journal	2
Information Systems Frontiers	2
Interacting with Computers	2
Expert Systems	2
Journal of Research and Practice in Information Technology	2
Journal of Biomedical Informatics	2
Innovations in Systems and Software Engineering	2
Health Informatics Journal	2
International Journal of Software Engineering and its Applications	2
International Review on Computers and Software	2
MIS Quarterly	2

systems (Yang et al., 2014), cloud systems in two reviews (Mellado et al., 2010; Iankoulova and Daneva, 2012), service-oriented systems (Teka et al., 2012), and virtual reality systems (Santos et al., 2013).

We also found quite a few reviews (5) that dealt with the use of support technology for RE: wikies (Lai et al., 2012), recommender systems (Mohebzada et al., 2012), requirements management tools (Reiner, 2009), knowledge sharing platforms (Silaber and Breu, 2014) and technology transfer decision support (Ivarsson and Gorschek, 2009). However, in our experience, it seems there are only two SRs that investigated evidence concerning a possible relationship between use of a RE support tool/techniques and the impact a tool/technique makes on its environment of use. The review of Sillaber and Breu (2014) focused on understanding the evidence that existed regarding the impact of a particular type of infrastructure (namely knowledge sharing platforms) on RE

processes in a particular context (namely, distributed), while the one of Abrahao et al. (2009) evaluated the evidence on the use of usability techniques for agent-based systems. Last, one SR concerning the adoption of empirical RE in a specific geographic region (Brazil) has been published (Oliveira et al., 2013).

3.2.2. Comparison with two RE roadmap publications

In the RE literature, there are two publications that present RE roadmaps (Cheng and Attlee, 2007; Nuseibeh and Easterbrook, 2000). We used these papers to compare and contrast the topics from Table 3 (treated in the systematic reviews and the mapping studies in RE) and those topics put forward in the roadmaps. This allowed us to see how research evolved over time and what topics remained still under-researched in terms of aggregated evidence. Table 4 presents those topics from the two roadmaps that have been addressed until now and those that were not addressed so far. The rightmost column in Table 4 suggests that 6 areas could possibly benefit if we aggregate the available empirical research results produced in primary studies of the areas: (1) requirements scaling, (2) RE for self-management systems, (3) effect of system environment on RE, (4) impact of RE research on industry practice, (5) requirements negotiation, (6) conflict resolution.

3.2.3. Theoretical perspectives

The RE as a discipline grew out of multi-faceted interactions between practitioners from the corporate world and scholars from Software Engineering (SE) and Information Systems Research (ISR) schools. As a matter of fact, many RE textbooks grew out of experiences accumulated by practitioners in large corporate projects (Lauesen, 2002; Young, 2001; Robinson and Robinson, 2012) and many others grew out of the collective learning and wisdom of collaborating RE consulting practitioners and scholars (e.g. Alexander and Bujic, 2006; Pohl and Rupp, 2011; Maiden and Alexander, 2007). Moreover, RE scholars belonging to SE research schools were instrumental to establishing experiments-focused research practices and quantitative reasoning in empirical RE research. At the same time, ISR scholars helped establish the notion of RE as a socially constructed activity and actively sought to address the various concerns of deploying RE techniques in real-life organizational settings. They also put forward qualitative research design practices such as case study techniques (based on e.g. grounded theories, focus groups) that first originated in social sciences. This variety of backgrounds (industry practitioners and scholars from SE and ISR) added up to the breadth and depth of the conversation on empirical RE research over the years, which is reflected in the variety of theoretical perspectives deployed to the area.

To illustrate the variety of theoretical lenses used in empirical RE, we looked at the primary studies included in the three most recent systematic reviews in RE that are published in journals (Meth et al., 2013; Abelein and Paech, 2013; Yue et al., 2011) and that provide an exact count and references of the involved studies. Table 5 illustrates the penetration of theories of other disciplines into empirical RE. We note that this approach has of course limitations (i.e. the most recent reviews have as their topics user involvement which generally lends itself to investigation by using theories from social sciences); however, it serves the sole purpose to provide a general idea of the range of theoretical lenses that empirical RE research designs considered. In Table 5, each column indicates the theories that were used by the primary studies included in each review.

As we wanted to see the motivations for choosing theories and how these were used in empirical RE designs, we checked the primary studies included in each review. The first one (Meth et al., 2013) included 36 studies, the second (Abelein and Paech, 2013) – 58 studies, and the third (Yue et al., 2011) – 20 studies, respectively. The cells that are marked with a star (*) indicate that the authors

Table 3
RE topic addressed in systematic literature reviews and mapping studies.

RE techniques/practices/frameworks/approaches studied	Number of reviews
Requirements prioritization techniques (Herrmann and Daneva, 2008; Pitangueira et al., 2013; Rinkelevic et al., 2013; Pergher and Rossi, 2013)	4
Requirements specification techniques/notations (Teka et al., 2012; Da Silva and Benitti, 2011; Condori-Fernandez et al., 2009; Amyot and Mussbacher, 2011)	4
Security requirements (Iankoulova and Daneva, 2012; Souag et al., 2012; Mellado, 2009; Goudarzi et al., 2013)	4
Creativity techniques for RE (Saha et al., 2012; Lemos et al., 2012; Nguyen, 2009)	3
User participation and client involvement (Bano and Zowghi, 2013; Abelein and Paech, 2013)	2
Stakeholder identification (Pacheco and Garcia, 2012; Carla and Ivan, 2008)	2
Goal-oriented RE frameworks (Ghanavati et al., 2011; Horkoff et al., 2014)	2
Requirements triage and selection (Khurum et al., 2012)	2
Requirements elicitation techniques (Davis et al., 2006; Ouhbi et al., 2013)	2
Requirements analysis techniques (Yue et al., 2011; Aguilar et al., 2010)	2
Automated requirements elicitation techniques (Meth et al., 2013)	1
Requirements modeling and analysis techniques for self-adaptive systems (Yang et al., 2014)	1
Tracing techniques (Torkar et al., 2012)	1
Generation of requirements specification from SE models (Nicolás and Toval, 2009)	1
Technology transfer decision support approaches (Ivarson et al., 2009)	1
Model-driven RE techniques (Loniewski et al., 2010)	1
Transformational approaches between user requirements models and analysis models (Yue et al., 2011)	1
Requirements management tools (Reiner 2009)	1
Use of knowledge sharing platforms for RE (Silaber and Breu, 2014)	1
Knowledge creation (Schneider et al., 2013)	1
Requirements-based software testing techniques	1
Requirements evolution approaches (Zhang et al., 2012)	1
RE-specific wikis for distributed context (Lai et al., 2012)	1
RE techniques for distributed development projects (Ebling et al., 2009)	1
Data quality requirements (Guerra-Garcia et al., 2010)	1
Approaches for determining business value of requirements (Racheva et al., 2009)	1
Quality requirements management techniques (Svensson et al., 2010)	1
RE techniques for product derivation (Rabiser, 2010)	1
Requirements reuse techniques (De Azambuja et al., 2009)	1
Risk and safeguard practices in global RE (Lopez et al., 2009)	1
Techniques for aligning requirements and testing (Barmi et al., 2011)	1
Usability requirements elicitation (Ormeño and Panach, 2013)	1
Practices for construction high-quality requirements models (El-Attar and Miller, 2012)	1
Recommender systems for RE (Mohebzada, 2012)	1
RE techniques for software product lines (Aves et al., 2010)	1
RE education (Ouhbi et al., 2013)	1
Causes of requirements change (Bano et al., 2012)	1
Release planning models (Svahnberg et al., 2012)	1
Requirements errors (Walia and Carver, 2013)	1

of a primary study that used the respective theory, motivated their choice for this theory.

Last, the number in brackets after each theory indicates the number of primary studies that used the respective theory. For example, in the review of Abelein and Paech (2013), nine primary studies used the theoretical perspective of participatory design and motivated why they chose it.

We note that in these three reviews not all primary studies explicitly stated the theory they used. Also, some primary studies were exploratory in nature and used a qualitative research method that assumes no theory as a starting point for the empirical research undertaken.

We think that Table 5 suggests a positive development as RE is multidisciplinary and understanding it necessarily implies the application of multiple perspectives. The table indicates that theoretical perspectives that originated in the Computer Science and Software Engineering field are most of the time motivated when are put into use in empirical RE studies. However, our unsystematic check suggests that theories that are borrowed from other disciplines (e.g. sociology, organizational behavior) were mostly referred to, with little or no explicit discussion on how the concepts of the theory were translated into the empirical RE setting. While in some cases this might be justifiable, voices from the ESE community were raised that the risk of such a practice might be

Table 4
Topics in SR and mapping studies and the two roadmap papers.

Roadmap	Year	Topics addressed until now in SRs	Topics that are not addressed until now in SRs
Cheng, Attlee	2007	• Security requirements • Global RE • Distributed RE • RE education	• Requirements scaling • RE for self-management systems • Effect of system environment on RE • Impact of RE research on industry practice
Nuseibeh, Easterbrook	2000	• Techniques for formally modeling and analyzing properties of the environment • Requirements elicitation • Non-functional requirements • Reuse of models • RE education	• Requirements negotiation • Conflict resolution

Table 5
Examples of theories used in three systematic reviews.

Meth et al. (2013); 36 studies	Abelein and Paech (2013); 58 studies	Yue et al. (2011); 20 studies
Corpus-based frequency profiling*	Technology acceptance model	Transformational paradigm*
Signal processing*	Usability model* (2)	Object-oriented paradigm* (5)
Domain ontology* (4)	Organizational theory	Linguistic analysis* (2)
Symbolic and connectionist paradigm	Collaboration engineering theory	Patterns*
Transformational paradigm* (3)	Technology defusing theory	Related triad
Probabilistic classification theory*	Marketing diffusion theory	Twin Peaks model
Design recovery process	Participatory design* (9)	Metamodelling paradigm
Object oriented paradigm* (4)	Cultural probes theory	Formal grammar
Data mining	Empirical learning	Data type theory*
Organizational learning*	Action theory	
Data structures*	User configuration theory	
Problem-solution domain reasoning (2)	User-centric design paradigm (3)	
Case-based reasoning	Stakeholder theory	
Similarity analysis* (2)	Reference framework for software process improvement	
Apprenticeship multi-strategy learning theory	Media richness theory (2)	
Learning theory	Socio-technical theoretical lens	
Unsupervised clustering	Contextual design	
Classification theory		
Two-level grammar		
Pattern theory		
Graph theory		

significant. As indicated in (Sim et al., 2001), approaches and theories from other disciplines can rarely be applied wholesale without first studying their underlying assumptions. If we do not explicitly state how the assumptions of a theory match the settings to which it is applied, then we might commit critical errors or pose a serious threat to validity of the results obtained. More discussion, therefore, on the assumptions behind choosing and using a theory from another discipline, for the purpose of RE research would help readers of empirical RE papers better understand and evaluate the validity of the results.

3.3. This special issue

For this special issue, we called for contributions that (1) evaluate techniques from ESE for suitability and inclusion in RE studies, or (2) address RE problems and solutions in new domains by deploying empirical research methods. Our call for papers to this special issue brought 17 submissions. All were subjected to a systematic multiple-stages review process with the engaged participation of at least three reviewers. Five high-quality papers were selected for inclusion in this issue.

The paper "Software product management – An industry evaluation" by Christof Ebert and Sjaak Brinkkemper focuses on product management as a key driver for RE and reports on an field study with practitioners from fifteen organizations worldwide complemented with an industry survey, concerning the role of product managers and its relationship to project success. The key finding is that increasing institutionalization of a consistent and empowered product management role leads to an improved success rate of projects in terms of schedule predictability, quality and project duration.

The paper of R.J. Wieringa, "Empirical research methods for technology validation: Scaling up to practice" answers the question of how to generalize from empirical RE validation research to future practice. The author elaborates on four approaches that RE researchers might consider for use in empirical research designs that aim at simulating future practical use of RE technology. These approaches are expert opinions, single-case mechanism experiments, technical action research and statistical difference-making experiments.

The paper of Sami Jantunen and Donal Gausse "Using a grounded theory approach for exploring software product management challenges", demonstrates the use of a grounded theory research

method in an exploratory study about market-driven RE practices and challenges. The author's theorizing effort is focused on developing a theory proposal that used the notions of design problems and paradigm shifts to explain why the companies participating in the study experienced specific he challenges in market-driven RE.

The paper of Johan Hoorn, "Stakeholder logistics of an interactive system" reports on an empirical study that uses the theoretical constructs of the Stakeholder Logistics formulate hypotheses about the relationships between four variables: Usability, Efficiency and Effectiveness and Satisfaction. Using empirical data from professional users and projects in the banking and heath care sector, the author carries out a hypotheses testing exercise. The author's findings indicate that Efficiency and Effectiveness seem more important than usability in explaining why stakeholders are satisfied with a system of not.

The paper of Fabio Massacci, Federica Paci, Le Minh Sang Trana, and Alessandra Tedeschi, "Assessing a requirements evolution approach: Empirical studies in the air traffic management domain" reports on the empirical evaluation of the effectiveness of a novel approach for modeling and reasoning about requirements evolution. Part of the study responds to the question about whether the effectiveness depends on the user's level of knowledge of the approach and of the application domain. The authors present three quantitative studies in which hypotheses are tested on data collected from three different groups of participants that differ in terms of exposure to the approach and to the application domain.

4. Conclusions

This editorial shows that empirical approaches to the study of RE phenomena have accompanies the RE discipline since its very beginning and have received much attention over the past 20 years, adding up to a broad variety in terms of research methods deployed, theoretical lenses and contextual settings. The RE community demonstrated remarkable commitment to deploying theories from other disciplines in the design of empirical RE research. Aggregating evidence from empirical RE studies and generalizing knowledge claims have been however a bumpy road. While a steady increase in the number of empirical studies each year is a positive development, yet to absorb the full benefits of the produced empirical studies, empirical research activities need to be coupled with reflections on the use of the deployed theories and possibly embed the learning and the evidence from the RE studies into the process of

extending the existing theories from other disciplines or creating new theories specific to the area of RE.

Compared to the research agendas outlined in the two RE roadmap publications (Cheng and Attlee, 2007; Nuseibeh and Easterbrook, 2000), we found that:

1. The RE sub-areas for which empirical RE efforts were focused on aggregating evidence are: requirements elicitation, specification, prioritization and tracing and as well as 'user-front-end' sub-areas as e.g. user involvement and stakeholder analysis. Techniques for these areas have been evaluated by means of using the systematic literature review techniques (Kitchenham, 2006).
2. Aggregating evidence about requirements validation techniques, requirements negotiation techniques (e.g. conflict resolution), requirements scaling and RE for systems of systems still remains to be done. Efforts to consolidate knowledge in these sub-areas could be a line for future research.
3. Most RE empirical claim aggregation efforts focused on providing better answers to old questions (e.g. effectiveness of techniques specific to a sub-area such as elicitation, prioritization). There is also a recent trend in evaluating evidence pertaining to using RE techniques in specific new contexts of development (such as distributed). However, very few reviews indicated any focus on new application domains such as service systems, internet-of-things systems, game and health-care systems. As the importance of those is growing, we think that evaluating the evidence provided by empirical RE research in these areas is a worthwhile endeavor.
4. While the interest in exploration of using theories from other disciplines seem overwhelming and leads to intense research activity, very little seems to have been done on sharing experiences on how to borrow a theory from another discipline and put it in productive use for the purpose of empirical RE research. Neither there seem to be any effort to aggregate the collective learning about the use of theories. Reflection on theory use therefore is a relevant and worthwhile activity for the future.

Acknowledgements

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