Approaches to improve researcher-practitioner communication in joint software engineering research

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ABSTRACT

Background: Joint research between industry and academia benefits both communities. For researchers, working with practitioners, it is a chance to collect empirical data and test research-based solution proposals. For practitioners, one of the main benefits is access to scientific knowledge. Despite the benefits, there is a gap between industry and academia that could be addressed through more joint research work.

Objective: In this thesis, we report experiences from researcher-practitioner communication in joint software engineering research. Furthermore, we explore approaches to improve researcher-practitioner communication.

Methodology: We use design science as a frame to present the conducted research. The problem domain is related to the communication between researchers and practitioners, while the solution domains span several approaches to improve communication. To identify and validate approaches, we conducted two case studies. Finally, we propose interactive rapid reviews to improve communication. The proposal is based on a literature review and extends an existing method by reinforcing the researcher-practitioner interaction.

Contributions: We present a view of researchers-practitioners communication where we notice the importance of common terminology and the influence of the context. We explore three approaches to improve researcher-practitioner communication in joint research: 1) SERP taxonomies to use a common terminology to express industry challenges and research results. 2) Communication facilitators as context characteristics that help to smooth communication. 3) A proposal to conduct interactive rapid reviews to involve practitioners in secondary studies and foster knowledge exchange.

Conclusion: This thesis highlights the importance of managing communication in joint research projects. Besides, it describes three approaches to increase knowledge exchange between industry and academia and, consequently, impact the software development practice and academic research and teaching.

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This licentiate thesis is an important milestone in my Ph.D journey. I want to express my appreciation and gratitude shortly:

This project is funded by the ELLIIT strategic area funded by the Swedish government. Doing my Ph.D. and living in Sweden has been not only an incredible academic experience of researching industry-academia. It is also an eye-opening life experience to reflect on the role of science in society and the need to listen to scientists to address global humanity problems. Så, tack så mycket!

I have been just lucky to have two supervisors! Dr. Emelie Engström and Prof. Martin Höst if I would have to choose only one thing to thank, I would say thanks for inspiring my career with your example. Thank you, Martin, for always making the point on the fundamental questioning that must guide research. Thank you, Emelie, for reinforcing that research has to be transparent and systematic. I'm happy to keep working with both of you!

Co-authors: Dr. Elizabeth Bjarnason, Prof. Per Runeson, Dr. Nauman Bin Ali, and again Dr. Emelie Engström and Prof. Martin Höst. I have learned and enjoyed working with you.

Thanks to the members of the Software Engineering Research Group for making academic life very enjoyable, especially for those with whom I have shared in research and teaching: Per, Alma, Daniel, Ramus, Song, Joan, Martin, Björn, Elizabeth, Adha, Emelie, and Markus. Thanks to the Department of Computer Science personnel which supports us in many different ways. Special thanks to Carina, Peter, Birger, and Ulrika.

Para toda mi familia, los Rico y los Rangel. Nuestras familias se han forjado en base del trabajo y la educación. Siempre me siento un portador de esos estandartes. Espero estar representandolos bien.

Hilda, Sergio, and Juliana: In my Ph.D. I learn about science, research, communication, software engineering, education, and other nice stuff. With you, I learn about being, loving, living, and other invaluable stuff. Thank you. I love you!

Tack! Gracias! Thanks!
Sergio Henry Rico Rangel
Lund, 2020

LIST OF PUBLICATIONS

This thesis consists of an introduction and a compilation of three papers. The introduction gives an overview of the research topic, and it describes the papers and contributions briefly. Papers I-III have been formatted in this thesis template without additional changes from the original publications.

Publications included in the thesis

I **A taxonomy for improving industry-academia communication in IoT vulnerability management**
Sergio Rico, Emelie Engström and Martin Höst
In proceedings of 45th Euromicro Conference on Software Engineering and Advanced Applications (SEAA), 2019.
DOI: 10.1109/SEAA.2019.00014

II **A Case Study of Industry-Academia Communication in a Joint Software Engineering Research Project**
Sergio Rico, Elizabeth Bjarnason,Emelie Engström, Martin Höst, and Per Runeson
In submission to a journal, 2020.

III **Guidelines for conducting interactive rapid reviews in software engineering - from a focus on technology transfer to knowledge exchange**
Sergio Rico, Nauman Bin Ali, Emelie Engström and Martin Höst
Technical Report, 2020.
DOI: 10.5281/zenodo.4327725

Related Publications

IV **Exploring and improving industry-academia communication in software engineering**
Sergio Rico
In Proceedings of the International Conference on Evaluation and Assessment in Software Engineering (Doctoral Symposium), 2020.
DOI: 10.1145/3383219.3386125

Contribution statement

All papers included in this thesis have been co-authored with other researchers. The authors' individual contributions to Papers I-III are as follows:

Paper I
Sergio Rico, Dr. Emelie Engström, and Prof. Martin Höst designed the study. Sergio Rico and Dr. Emelie Engström lead the taxonomy development. Sergio Rico was responsible for designing and preparing the interviews and focus group. Sergio Rico was the first author of the paper and responsible for the writing. All the authors contributed to reviewing and editing the paper.

Paper II
Dr. Elizabeth Bjarnson, Dr. Emelie Engström, Prof. Martin Höst and Sergio Rico designed the study. The timeline retrospective evaluation was conducted in the frame of the evaluation of the research program prepared by Dr. Elizabeth Bjarnason. Sergio Rico and Dr. Elizabeth Bjarnason conducted and reported the analysis. Sergio Rico was responsible for designing and reporting the survey. Sergio Rico was the first author of the paper and responsible for the writing. Dr. Elizabeth Bjarnson, Dr. Emelie Engström, Prof. Martin Höst, and Prof. Per Runeson contributed to editing and reviewing the paper.

Paper III
Sergio Rico proposed the initial idea. Sergio Rico conducted the literature review about Rapid Reviews in medicine supported by co-authors. The current proposal evolved through discussions with the co-authors. Sergio Rico was the main responsible for writing the report. Sergio Rico was the first author of the paper and responsible for the writing. Dr. Nauman Bin Ali, Dr. Emelie Engström, and Prof. Martin Höst contributed to editing and reviewing the paper.

Contents

INTRODUCTION

Industry and academia may benefit from a strong relationship. This connection is even more critical in applied disciplines like software engineering. However, some researchers argue that the connection between research and industry in software engineering is still low [22, 23, 30]. Some of the reasons for the divide are the lack of industry context in research [5], low relevance and impact of research results [22], and low joint work between industry and academia [24].

One of the initiatives to foster the industry-academia relationship is joint research [16]. Working with industry, researchers may better understand industry challenges, collect empirical data, test their ideas in real scenarios, and get insights from industry to update university curricula. Similarly, practitioners get benefit from getting closer to academia. They may apply research results to solve problems and get research awareness [2, 46]. A vital element to fruitful joint work is the researcher-practitioner communication.

The central topic of this thesis is the communication between researchers and practitioners in software engineering. To adress this topic, we adopt a design science perspective [20, 28, 39]. Consequently, we investigate three approaches (solution domain) that are relevant to a class of problems (problem domain). By analyzing the problem-solution pair, we gain an understanding of the communication problem and formulate generalizable prescriptive knowledge in the form of technological rules.

Research Goals

The following research goals (RG) aim to investigate researcher-practitioner communication in joint projects. RG1 aims to identify key aspects to consider when studying communication. While RG2 explores three approaches to improve communication.

RG1: To explore researcher-practitioner communication in joint projects.

We conducted two case studies to identify variables that influence communication. In Paper I, we developed and evaluated a taxonomy to support communication in a joint project in software vulnerability management. Specifically, we used the taxonomy to connect research results and industry challenges. In Paper II, we studied communication between researchers and practitioners in a joint project in the area of software testing. These case studies provide elements to form a view of researcher-practitioner communication.

RG2: To explore approaches to improve researcher-practitioner communication.

We explore three approaches to improve researcher-practitioner communication as follows:

1. The SERP taxonomy architecture [36] supports communication by providing a common terminology to express research results and industry challenges. We develop and evaluate a SERP taxonomy in a new context.

2. In a joint research project between industry-academia, we investigated in retrospective the researcher-practitioner communication to identify what facilitates good industry-academia communication.

3. We elaborated a proposal named interactive rapid reviews, to conduct secondary studies with practitioners in software in an agile manner to make them more interactive and thus, foster knowledge exchange.

1 Communication framework

In this section, we present how we frame researcher-practitioner communication in this thesis. Communication has a plethora of definitions according to the field where it is studied [17]. Some of the conceptual components around the definitions include verbal exchange, mutual understanding, interaction, process, uncertainty, transmission, linking, channels, memory replication, time, power [18]. The model that we use in this thesis (see Figure 1) does not cover all these concepts but focus on two important dimensions named relational and informational. The relational dimension involves the human relationship between the communicating parties, and the informational dimension regards the exchange of information and co-construction of meaning and knowledge [10, 27]. Thus, to study researcher-practitioner communication, we investigate the exchange of information about a topic (informational) and the relationship between researchers and practitioners (relational). These two dimensions need to be seen in conjunction because they affect each other. Moreover, communication happens within a context that also influences it. To sum up we have the following constitutes:

Communicating parties: Represented by the researcher and practitioner Figure 1. By practitioners, we refer to people working in organizations, public or private, in software engineering activities. By researcher, we mean people working in higher education institutions and research institutes. Note that this does not include scientists doing research and development in industrial organizations. Although much of this thesis content may apply for communication in-house in

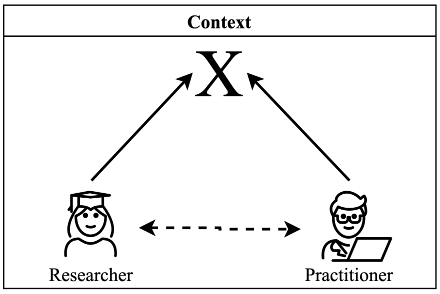

Figure 1: The researcher-practitioner communication model around the X topic combines information exchange (arrows) and parties relationship(dashed arrow) within a context.

organizations with research units, we investigate mainly the industry-academia divide.

Context: The context, rectangle in the figure, is where the communication takes place, i.e., scenarios where researchers and practitioners interact. The communication context may be specific, e.g., meetings, workshops, interviews, presentations, or more general like the whole joint research project. We use the term communication instance to denote a specific time where researcher and practitioner communicate about a topic X in a particular context.

X: The communication topic is what the communication parties exchange. The topic may be related to the research as such or to the project management. Some examples are the research topic when defining the scope, project, a testing technique, industry challenges, the duration and frequency of meetings.

2 Research approach

This thesis is developed as a collection of three papers and adopts design science to frame the included research studies and contributions [39]. Design science aims to solve real-world problems by building and evaluating interventions (artifacts) relevant for a class of problems, i.e., problems with similar contexts [28]. The interventions are prescriptive knowledge that is captured and presented as technological rules [28,44]. A technological rule may be presented in the form *To achieve* *<effect> in <context> apply <intervention>* [1,39].

Engström et al. [20] present a view of the interaction between the problem domain and the solution domain in design science. We use this model to describe the research goals and the main focus of the papers included in this thesis (Figure 2). Regarding the research goals, RG1 aims to explore the problem domain by studying two different joint research projects, while RG2 is focused on the design and evaluation of interventions that aim to improve communication. In Figure 2, the arrows over the model show the main focus of the included papers in the design model as follows.

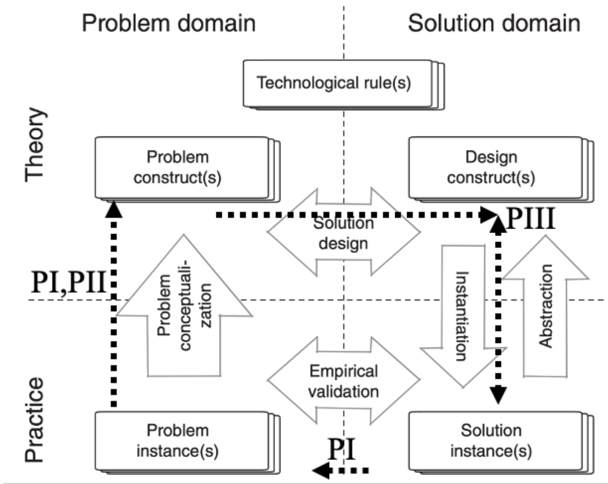

Figure 2: A view of the papers included in this thesis mapped in the design science research model by Engström et al. [20]

Paper I serves two purposes. First, it contributes to the problem conceptualization by studying the case related to the need for a common terminology. Second, it validates a previous solution on how to improve industry-academia communication by applying it to a new joint project about vulnerability management in IoT systems. The joint project studied was developed for three years, with six industrial organizations and three research groups.

The focus of Paper II is on what facilitates communication in a joint project and the role of communication concerning the project outcomes. Some differences compared to Paper I are that we studied the project in retrospect, the project was larger in duration, and the industry partners were both large organizations. The paper reports a case study about communication in a joint project between industry and academia in software testing.

Finally, Paper III describes a solution to improve industry-academia communication by conducting interactive rapid reviews with practitioners. The proposal is based on 1) the authors' Reflections on researcher-practitioner interaction in secondary studies in software engineering, 2) a literature review of rapid reviews in medicine, 3) a review of software engineering literature on the practitioners involvement in secondary studies. The proposal for interactive rapid reviews extends the existent guidelines for rapid reviews to make the process more agile to foster knowledge exchange between researchers and practitioners.

As is mentioned by Runeson et al. [39], "The design science paradigm may embrace the use of a multitude of research methods". Paper I is an exploratory validation of the SERP taxonomy architecture concerning the need for improving communication and linking industry challenges and research results. Paper II is an exploratory case study that follows the guidelines by Runeson et al. [40]. Exploratory case studies have as purpose to understand a phenomenon in the real setting, which makes them useful for conceptualization. Paper III is an exploratory design study where research about secondary studies in medicine and software engineering is reviewed from the industry-academia perspective and researcher-practitioner communication. The data collection activities include interviews and focus group for Paper I, and timeline-based method [8] for project retrospective and survey for Paper II.

3 Included papers

This thesis is a collection of papers. In the following subsections, each of the included papers is described.

3.1 Paper I: Towards a common language to link challenges and solutions

Title: *A taxonomy for improving industry-academia communication in IoT vulnerability management*

The case under study in this paper is a joint project between three academic groups and six companies. In this type of project, the terminology mismatch may create communication gaps [23]. To support communication in similar scenarios, the SERP-architecture proposes developing taxonomies to describe challenges and research results using a common terminology [36].

Paper I reports on the development and evaluation of SERP-MENTION, a SERP-taxonomy within the context of a project about software vulnerability management [37]. Previous uses of SERP-taxonomies in software testing [7, 19] have shown SERP taxonomies' potential to connect industry and practice. To build the first version, we reviewed the standards of IoT security. The second version was developed after interviewing researchers. We conducted a workshop with company representatives to validate and extend the taxonomy. As the final step to evaluate the taxonomy, we extracted solutions and challenges from a sample of papers, and then we linked potential solutions with industry challenges. We validated the usefulness of SERP-taxonomies to support the description of research results and industry challenges and link results from academia with problems from industry.

3.2 Paper II: Exploring communication in a joint project

Title: *A Case Study of Industry-Academia Communication in a Joint Software Engineering Research Project*

Researchers and practitioners may communicate in several contexts [35]. One of the most common contexts where they work together is in joint projects [24]. For this reason, we studied the project to gain knowledge about the role of communication, its impact, and the influence of the context.

Paper II is a case study. The case under study was a joint project part of a long-term (10 years) joint program with both academic institutions and the industry. The specific project was conducted during the last years of the program in the area of software testing. The study comprised two main steps, where we collected data. In the first phase, we used a retrospective timeline-based method to collect data [8]. We transcribed and coded the recordings of the data collection activities and followed techniques of thematic analysis. We coded the following information for each instance of communication: communicating parties, the environment where the exchange took place, the content, and the effects. During the analysis, we identified facilitators for communication. We denoted as facilitators characteristics of the context that favor communication, for example, having a long term relationship or having regular meetings. During the second phase, we validated the results by surveying researchers and practitioners. In this case study, we followed the guidelines proposed by Runeson et al. [40] to conduct case studies in software engineering.

3.3 Paper III: A proposal to foster industry-academia communication through Interactive Rapid Reviews

Title: *Guidelines for conducting interactive rapid reviews in software engineering - from a focus on technology transfer to knowledge exchange*

In Paper III, we propose steps to conduct interactive rapid reviews in software engineering based on a review of rapid reviews in medicine, and proposals for rapid reviews in software engineering. We see that secondary studies in software engineering are often not involving practitioners in the process. We envision interactive rapid reviews as a way to bridge the gap between research and practice. Rapid Reviews are widely used in Evidence-Based medicine to synthesize research evidence in short time and support decision making [29]. Evidence-based software engineering is inspired by evidence-based medicine. Also in software engineering, Cartaxo et al. [14] have proposed the use of rapid reviews to support decision making. In our proposal, we extend their proposal by reinforcing the interaction with practitioners. We named our proposal Interactive Rapid Reviews. We think that increasing the practitioners' involvement impacts the relevance of the outcomes. Overall, in interactive rapid reviews, we see a scenario where researchers and practitioners may develop mutual understanding and pave the way for future joint work.

4 Related Work

4.1 Industry-Academia interaction

The impact of public-funded research has been a topic of interest for researchers among different disciplines. Some of the benefits of industry-academia joint work include production of new knowledge, training of skilled graduates, support of scientific networks, new companies, and providing social knowledge [42]. To achieve these benefits, industry and academia interact in a complex relationship that goes beyond academics publishing papers and teaching [6]. In the analysis of industry-academia links, Scott et al. [43] identified four type of communication channels between industry and academia. The first channel, codification/artifacts, refers to the knowledge difussion by codification in publication, patents, and prototypes. The second channel, denoted cooperation, refers to the formal partnership between industry and academia like in joint ventures and personal exchange i.e., academics in companies and practitioners in academia. The third channel is contacts and it is identified as one of the most important channel to build strong relationships. Some examples of these contacts are scientific networks, science parks, technology transfer offices [31]. The authors mention the importance of physical distance, arguing that proximity may contribute to increase exchange [9]. Finally, the fourth channel are contracts as formal contractual links. Some examples of contracts are licences, contract research, and consulting.

4.2 Researcher-practitioner communication

Researchers have investigated the communication between industry and academia by taking different approaches depending on the research discipline. Weiss published in 1979 seven models to describe how policymakers used social science research [45]. Among the models the author shows the need to connect researchers with policy-makers and in the social and political sphere to increase the use of research in policy-making. More recently, also in social science [34], researchers have analyzed the exchange between researchers and decision makers. The authors highlight the importance of research communication and interaction to increase the use of research. Furthermore, the authors suggest the following elements for researchers to enhance research use by policymakers: knowledge translation, personal contacts, contextual research, credibility, leadership, and formal partnerships.

In accounting management, Mitchell reflects on the need to study real-world practice [33] to influence not only other researchers but also real practice. However, the author also recognizes the importance of research as an independent activity of current practices. Therefore he proposes actions to increase the research-practice integration. The actions include involving the practitioners in the research process e.g., action-research, make practitioners a target audience for the researchers but making the research outcomes more understandable for practitioners and disseminate results out of academia.

In library and information science, Haddow and Klobas [26] identify gaps between research and practice, including knowledge, culture, motivation, relevance, immediacy, publication, reading, terminology, activity, education, and temporal. The authors suggest two interventions to bridge the gaps. The first intervention is to increase the practitioner involvement in research under the assumption that practitioners will contribute more to research if they verify the research relevance and impact in their context. The second intervention is to improve the communication of research results to practice. For the authors, traditional research papers are complex to read for practitioners, therefore, they suggest diversifying the mediums by which research results are communicated to impact practice.

4.3 Industry-Academia interaction in software engineering

In software engineering, some of the terms used to describe industry-academia interactions include knowledge and technology transfer, knowledge translation, and industry-academia collaboration. Despite some particularities that make them different, all the interactions are based on communication.

Technology transfer is presented by Gorshek et al. [25]. The authors present a model that emphasizes cooperation from their empirical experience working with industry. Similarly, but focusing more the bi-directional character of the knowledge exchange, Mikkonen et al. [32] present a model for continuous and collaborative technology transfer. Knowledge transfer is a similar term that has been also used. An example is the work of Cartaxo et al. [15] where the authors present a model to transfer knowledge from academia to companies. In this model, the researcher acts as a transfer-agent, and they use evidence summaries as a transfer medium. Badampudi et al. [4] claim that the knowledge needs to be translated to the industry. Thus, they propose guidelines to translate knowledge into software engineering practice. In a systematic literature review, Garousi et al. [23] present challenges and best practices to run industry-academia collaboration. In their study, communication is included in terms of how to deal with meetings and terminology mismatch.

More specific mediums to communicate research results to the industry are the visual abstract template for design science research [44], evidence briefings as a template to present evidence from secondary studies [15], and the SERP-architecture [36] to link industry challenges and research results.

5 Results and Contributions

One general contribution of this thesis is that it highlights researcher-practitioner communication as an important research topic. By understanding what affects communication and how to foster practitioner-researcher joint work, the scientific community may get insights into managing communication in joint research to reduce the gap and increase the research impact. The contributions of this thesis are presented according to the research goals.

5.1 RG1: To explore researcher-practitioner communication in joint research projects

In Paper I, we developed SERP-MENTION, a taxonomy to support communication between researchers and practitioners in a joint project in the area of Internet of things (IoT) software vulnerability management. IoT is still an emergent topic both in research and industry. Consequently, researchers and practitioners who participated in the project had different views and referents about the project's terminology. A concrete example is that although all the companies involved needed to handle vulnerabilities, practitioners had different concerns, awareness, and challenges according to their contexts. We conducted a workshop where researchers and practitioners described challenges in their own words and after using the taxonomy. In some cases, we could see how the same challenge was described in more detail by using the taxonomy, including context elements, and more understandable for the other participants. From Paper I, we noticed the need and benefits of a common terminology when researchers and practitioners work in joint research.

In Paper II, we analyzed the communication in a research project about software testing conducted at the end of a ten-year research program between industry and academia. At the end of the project, researchers and practitioners evaluated some of the project's collaborative aspects using a timeline retrospective session. We transcribed the three-hour retrospective discussion and coded it with respect to industry-academia communication. We extracted all communication instances and coded them according to our communication model. In the material, we identified communication parties, the context of communication, and the communication outcome. From this coding and analysis, we found two types of results regarding communication. First, we noticed that some characteristics of the context influenced the communication between researchers and practitioners positively. We denoted these characteristics as facilitators. For example, both researchers and practitioners mentioned that meetings style and frequency facilitated sharing and discussing needs, ideas, and results. Second, we observed that some communication instances affected the project outcomes. For example, two representatives described that they started to change the test strategy after discussing research results with researchers. Thus, we identified project outcomes promoted by good communication. In Paper II, we highlight the importance of the communication context to facilitate researcher-practitioner communication. Besides, we identified that some communication instances promoted project outcomes.

In Paper III, we elaborate on a proposal to conduct interactive rapid reviews in software engineering. This proposal's primary motivation was finding a way to increase researcher-practitioner interaction and, therefore, promote knowledge exchange. Researchers have widely accepted evidence-based software engineering. Evidence of that is the number of systematic literature reviews and mapping studies published recently. However, secondary studies seem to be mainly used by researchers in academia [21]. Practitioners rarely get involved in the process, and the results often are only disseminated among academics. Thus, we reviewed other approaches in evidence-based medicine and found rapid reviews as an approach to synthesize knowledge from research results in a timely fashion. Rapid reviews have also been used by researchers in software engineering to support decision-making [12].

In our proposal, we reinforce the interaction between researchers and practitioners when conducting a rapid review. The rapidness may be a characteristic that practitioners will appreciate. Nevertheless, for practitioners is also important that the rapid review considers their context. Thus, we foresee that increasing the interaction with the practitioner may enhance the relevance of the rapid review results. Besides, conducting a rapid review is an opportunity to exchange knowledge between research and practice. From Paper III, we recognize in reinforcing interaction an opportunity to learn more about the practitioner's context and favor the exchange between industry and academia.

Retaking the communication framework introduced in Section 1, we summarize the findings of this thesis (RG1). Regarding the communication parties, researchers in our case studies (Papers I and II) included both junior researchers like Ph.D. students and senior researchers. The joint projects offered a scenario for junior researchers to conduct studies with industry. On the other hand, practitioners involved in the joint project acted as liaisons between the company and the joint projects. Practitioners represented diverse organizations from start-up to big companies, although the companies were only big organizations in the long-term project (Paper II). We noticed some indications that researcher-practitioner communication also influenced communication in other scenarios outside the project. For researchers, by participating in joint projects, they updated university courses' content and promoted discussion in academic forums. Practitioners in the joint projects developed research awareness that was discussed with their colleagues inside the companies.

Concerning what researchers and practitioners communicate about, we observed of communication about the research topic, the project, and social aspects. The most common interaction is around the project's topic, in our cases, software vulnerability management, and software testing. The abstraction level varies depending on the participants. In the long-term project, we noticed that senior researchers and managers discussed the topics at a general level, while the detail of the research was discussed with practitioners directly involved in software development. Researchers and practitioners also communicate about the project as such, and again this communication depends on the participants involved. We identified communication instances at the strategic level, where topics were defined, long-term goals were established, and more practical-oriented discussions around the project to coordinate activities took place. In the social dimension, we noticed that a social network emerged in the long-term project where the participants interacted. This exchange led to new joint studies and projects.

Regarding the communication context, both cases, Paper I and Paper II, were joint formal and funded projects. In Paper II, we identified some of the more specific contexts where communication occurs and classified them into project environment, project-related meetings, and studies. The project environment refers to the whole project as a common space where researchers and practitioners interact without any specific relation to a study or activity. The project-related meetings were meetings to discuss the research project. These meetings vary along with the project, being more creative and open at the beginning when defining research topics, and more in the form of follow-up meetings to track the project progress. The major part of the joint work was during the project research studies. Some of the activities within the projects where researchers and practitioners interacted include researchers collecting data, e.g. surveys, interviews, and workshops; researchers presenting research results; co-supervision of master theses; co-creation sessions e.g. workshops and discussion meetings.

In summary, regarding the RG1, we have explored key communication aspects in each of the included papers. Paper I focus on the need for common terminology, Paper II on the communication context's influence, and Paper III on industry-academia interaction and research relevance. The discussion in these papers may guide researchers and practitioners in what to consider and how to manage or investigate communication in future joint projects.

5.2 RG2: To explore approaches to improve researcher-practitioner communication

We explore three approaches to improve researcher-practitioner communication as described below. For each of the approaches we have derivated a technological rule TR [28, 39].

SERP taxonomies

In Paper I, we have developed SERP-MENTION which aims to support industry-academia communication by developing a common terminology [36]. The taxonomy follows the SERP taxonomy architecture by developing a common terminology (SERP-MENTION). The main facets of the taxonomy are intervention, effect, scope and context. Each entry (challenge or solution) may be expresssed using one or more entities of each facet as *“To achieve <effect> during <scope> in context do <intervention>”*. For example one of the solutions found in the literature to deal with security in IoT systems is described as *“To improve the access control during the patch management, when having a large number of objects, do implement a security manager on top of the centralized IoT hub”*. From a set of academic papers, we linked challenges and solutions proposed where we saw the potential of the taxonomy to link research results and industry challenges.

In Paper I, we described how SERP-MENTION was developed. Besides, we evaluate its potential and usefulness. SERP taxonomies may be useful at the beginning of a joint project to formulate research questions in a holistic fashion and describe challenges in context. Besides, using the taxonomy may help researchers to increase consistency when searching relevant literature and presenting results. Based on the results of this paper we formulate the following technological rule:

TR1: To increase mutual understanding in an industry-academia joint project, develop SERP taxonomies when discussing practical challenges and potential solutions.

Context Facilitators

In Paper II, we identified three main communication contexts: project environment, project meeting, and research studies. For each context, we found characteristics, denoted facilitators, that contributed to enhance commmunication within the project. For the general project, we noticed that having a long-term project was beneficial. With a long-time horizon, researchers and practitioners could start new projects without new formalities otherwise needed to form a new project. Besides, researchers and practitioners already knew how to work together. This familiarity with working with the other encouraged new projects and promoted the engagement of new participants in the project. We noticed that practitioners’ active participation and their involvement were key when defining the research topics and planning the project during the project meetings. Having high participation of practitioners in the project meetings contributed to increasing the relevance of the research for practice. As a consequence, practitioners participated more, making communication smooth with researchers. An additional aspect of the meetings was that communication style and frequency contributed to creating a constructive environment where communication was fluid. It was easy to exchange ideas and experiences. Finally, concerning the research studies, researchers’ attitudes toward research, their involvement, and the research relevance were positive in communication with researchers. As a consequence, researchers and practitioners could improve the likeliness that the research results have an impact on practice.

TR2 is derivated from the context characteristics i.e. facilitators that contribut to good researcher-practitioner communication.

TR2: To enhance communication in a joint industry-academia software engineering research project, consider research relevance, practitioner atti-

tude towards research, practitioner involvement, frequency of communication and, long term collaboration.

Interactive rapid reviews

We propose interactive rapid reviews to synthesize knowledge from research results in an interactive way with practitioners. In conducting these reviews, we recognize a way to present research results for practitioners relevant in their context. Overall, we envision an opportunity to achieve mutual understanding and pave the way for future joint projects. An interactive rapid review may be used for researchers and practitioners along their relationship in joint projects. Before a formal project, a rapid review may be a way to explore mutual interest; when a joint project starts, an interactive rapid review may help to find relevant research. We also see scenarios where researchers conduct rapid reviews to identify research gaps and as a preliminary step before a systematic literature review. On the other side, interactive rapid reviews may help companies with research units to improve cooperation between research and development areas.

The steps to conducting an interactive rapid review are described in three phases: plan, perform, and report. During the planning phase, researchers prepare the review by getting familiarity with research results around the topic. This phase's main objective is to refine the problem into research questions, identify elements to describe the practitioner context, and set common expectations and responsibilities. In this phase, a preliminary version of the review protocol is developed. The protocol will keep track of the decisions and activities to conduct the review.

The second phase is to perform the review, and includes the search and the selection of the papers, and extraction and synthesis of data. Shortcuts are applied to assure that the review will be conducted in a timely fashion. Some of the common shortcuts in the search limit the results to specific venues, secondary studies, date, and only one search engine. When selecting papers, it is suggested to set strict exclusion criteria to limit the number of papers and leave this task to only one reviewer to avoid conflicts. The analysis of results usually involves only narrative synthesis, and more advanced analysis techniques are only suggested when having a large number of papers.

In the last phase, the results of the review are disseminated into the groups of interest. The results are presented in a practitioner friendly fashion. The format of the reports is previously defined in agreement with the practitioners involved.

The researcher-practitioner interaction occurs at different moments during the review. At the beginning of the review, the participants agree with their involvement and the time required for each activity. The involvement may vary from consultancy at specific points to be part of the review team. The input from practitioners is vital to define the research questions and ensure that it considers their context. Having a dialogue with practitioners may contribute to refine research questions and decide about exclusion criteria. Before communicating the results, practitioners may co-design the format and plan activities to disseminate the review results. Furthermore, practitioners may present or co-present the review results as they know their colleagues and context better.

Based on Paper III, we formulate the TR3 as:

TR3: To increase research relevance and mutual understanding in industry-academia joint projects, conduct interactive rapid reviews

6 Limitations

Runeson et al. [39] propose to evaluate the contributions of design science research by assesing relevance, rigor and novelty. In this section, we adresss limitations of the general thesis regarding these factors. In addition, each of the included papers has a section that discusses limitations or threats to validity ralated to that specific study.

6.1 Relevance

Ideally, this research is relevant for all the researchers and practitioners working in the area of software engineering. However, we are aware of some aspects that may limit the contributions from this thesis. The studies reported in this thesis were conducted in collaboration between the Software Engineering Research Group (SERG) at Lund University and the Department of Software Engineering at the Blekinge Institute of Technology. Both groups have a long tradition of working close to industry, e.g. [25, 36, 38, 41, 46]. Although researching this environment may be considered as an advantage to study industry-academia communication, it is also a limitation because other researchers and practitioners do not collaborate in a similar environment. Consequently, in this thesis, we focus on joint-research projects where researchers and practitioners work together, a typical setting for collaboration [24].

Regarding the proposal for interactive rapid reviews, introducing a new proposal in the research community may be challenging. However, we have some indications that the proposal may be well received by researchers. First, the high acceptance of evidence-based software engineering in the research community. Researchers are familiar with conducting secondary studies, and they know the benefits and drawbacks. Second, in our experience, working with practitioners, they may lose the interest in the results of a systematic literature review if it takes long time, or if it is not relevant in their context. Hence, a interactive rapid review conducted in a timely manner may be more attractive to practitioners. Third, our proposal builds on the proposal by Cartaxo el al. [13, 14]. Cartaxo et al. conducted a survey about the viewpoints of rapid reviews by researchers in software engineering [11]. Based on the results we make two observations. First, the results give us some indication that the rapid review approach may be well accepted by the research community. Second, researchers may be open to use rapid reviews but they need more guidance on how to conduct these studies. Our proposal aims to meet this need.

Overall, in this thesis we assume that part of the researcher responsibilities is to work with practitioners and disseminate research results to the industry. This assumption may not be shared by other researchers. Notice that we do not mean that academic research have to serve the industry needs, instead we think it is important to keep some independence but also achieve a good level of mutual understanding and exchange.

6.2 Rigor

For each of the included papers, we present some concerns that may limitate the contributions in this thesis. In Paper I, SERP-MENTION was developed at the end of the joint project. For this reason, the taxonomy could not be tested entirely within the project. However, we could see the taxonomy's potential to describe industry challenges in a workshop with the project participants. Additionally, we validated the taxonomy by using it to express and link research results and industry challenges from a set of papers used as reference papers during the project. In relation to TR1, although we used only one case study, one of the research questions was related to the use in a new domain. This gives us some support to derivate TR1.

In Paper II, the timeline project retrospective sessions were not exclusively dedicated to studying communication in the project but also to evaluate other collaborative aspects. However, we noticed that the material collected was appropriate and sufficient to study communication according to our research questions. Another concern is that three of the co-authors in Paper II were highly involved in the project case. Even though familiarity with the project was helpful in dealing with data, this may also add bias to our analysis. To mitigate this risk, researchers less involved in the project were involved in the data analysis. Like in Paper I, we have investigated a single case study. Some of the observations may not be generalizable to other contexts with less tradition and joint work culture between industry and academia.

In Paper III, we elaborated the proposal of interactive rapid reviews based on reviewing medical papers about rapid reviews and stakeholder engagement in evidence-based medicine. We built on similar approaches proposed in software engineering and adapted to include a higher focus on researcher-practitioner interaction. Besides, we included some reflections from our experiences working with industry and conducting secondary studies. The main concern regarding our proposal's rigor is the lack of validation in a real scenario. The evaluation with practitioners is part of the future work in this thesis.

6.3 Novelty

From a general view, this thesis's main novelty is to focus in researcher-practitioner communication as a research topic in software engineering. Previous studies have studied the relation between industry and academia from an institutional perspective taking into account the inter-organizational relations e.g knowledge transfer offices or analyzing the impact of research. Other approaches like technology transfer, knowledge transfer, and knowledge translation have been proposed and evaluated models to work with industry. The work presented in this thesis shares some similarities with these approaches because all of them investigate the industry-academia relationship. However, the main focus of our work is on the researcher-practitioner communication. Although some of the approaches mention communication, they often limit communication to the interpersonal exchange and focus on channels, mediums, and meetings. In our view of communication, we include both the relational and informational dimensions and describe communication as a way of co-creating knowledge, sharing meanings, and developing mutual understanding. As far as we know, few studies have explicitly focused on the communication between researchers and practitioners in software engineering.

7 Future work

Given the exploratory nature of this thesis and the proposal of interactive rapid reviews, there are many diverse possibilities to build on this thesis. Below we describe some plans and ideas.

We plan to continue the work with interactive rapid reviews. Specifically, we have two ongoing case studies to validate the proposal in joint projects between researchers and practitioners. We would like to study multiple cases in software engineering to refine and evaluate the proposal. Future studies in other geographical contexts may give insights about the influence of cultural factors. On the other hand, we would like to support researchers working in research units in companies to evaluate how interactive rapid reviews may support communication between research and development units.

Students may eventually conduct interactive rapid reviews. Engaging students with secondary studies may positively affect in the long-term by familiarizing future practitioners with research evidence. Some researchers have investigated students conducting systematic literature reviews. Interactive rapid reviews may be more suitable for working with students, given the time to completion. These exercises may contribute to several goals. On the one hand, it is an opportunity to make students familiar with real industry challenges, and at the same time to learn how to deal with scientific literature and research evidence. On the other hand, it may be beneficial for the industry to explore research results and recruit students.

Developers of scientific software are a very interesting group of practitioners to test our strategies to communicate research results in software engineering. These practitioners are familiar with scientific literature and appreciate research results. Furthermore, they need to know more about existing software engineering techniques [3]. Thus, working together with scientific software developers may be a chance to test our approaches that may be applied later in larger group of practitioners.

We found some evidence of the influence of the participation in joint research in teaching. As many of the researchers are teaching to future practitioners in higher education. Some aspects to study further are the impact of joint research in education.

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INCLUDED PAPERS

CHAPTER I

A TAXONOMY FOR IMPROVING INDUSTRY-ACADEMIA COMMUNICATION IN IOT VULNERABILITY MANAGEMENT

Sergio Rico, Emelie Engström and Martin Höst,In proceedings of 45th Euromicro Conference on Software Engineering and Advanced Applications (SEAA), 2019. DOI: 10.1109/SEAA.2019.00014

Abstract

Background: In software engineering, industry-academia is a symbiotic relationship. Researchers need to be aware of the industry to produce relevant research, while practitioners are educated in academia and could take advantage of empirical research. The SERP taxonomy architecture is designed to support communication between practitioners and researchers in software engineering. **Objective:** The purpose of this study is to analyze to what extent the SERP taxonomy architecture is useful for improving communication between researchers and practitioners in IoT vulnerability management. **Method:** We developed a SERP taxonomy for IoT vulnerability management, SERP-MENTION, in an incremental way. Along the development, we evaluated the developed taxonomy in a project of industry academia collaboration. **Results:** In addition to the taxonomy itself we elaborate on the taxonomy development process and the potential of SERP-MENTION to support communication between researchers and practitioners within the area.

Conclusions: The SERP architecture can be used in a new field, it is perceived as useful by potential users to better describe and communicate research outputs and practical challenges in software vulnerability management.

1 Introduction

Empirical software engineering is an applied research area. Funding agencies and industry expect that research in the area of software engineering should affect and improve practices in industry. This is for example manifested in the "Triple Helix" model (e.g. [10]), emphasizing the interplay between university, industry, and government with funding agencies in innovation systems. Software engineering research can result in innovations in terms of new products, as well as in improved processes and tools that can be used in practice. Thus a shared understanding about practical challenges and proposed solutions between industry and academia is expected.

Shared understanding requires good communication in both directions of research results and perceived needs. If academia fails to understand what the actual problems in industry are, there is a risk of conducting irrelevant research in isolation. If communication fails in the other direction and industry is unaware of research in academia, there is a risk that improvement opportunities are missed. Poor communication between industry and academia may also lead to that improvement proposals are not sufficiently evaluated, e.g., through evaluations of research findings in form of tools and processes, as it requires collaboration. A basic assumption of this paper is that the communication between industry and academia can be improved, and that researchers and industrial organizations can benefit from the improvement.

Communication can take different forms. It can be direct communication, e.g. through meetings in joint research or discussions at conferences. It can also be indirect communication e.g. through published academic papers and technical reports. Regardless how communication is carried out, it is a problem if the communicating parts do not view the problem from the same abstraction level, not use the same terminology, or even understand each others' terminology. The construction and usage of a taxonomy can improve the communication by providing a common terminology and understanding of the domain and by catalyzing preciseness and completeness of problem descriptions. It can also support software process improvement when it comes to identifying relevant research results. Especially, in a SERP taxonomy [19] the scope of the classified research results are described in terms of which parts of the process they cover. In this paper we investigate if it is possible and meaningful to use a similar taxonomy approach to structure the area of security vulnerability management. We developed and evaluated a SERP taxonomy, SERP-MENTION (Software engineering research and practice in the management of vulnerabilities in the internet of things), in a joint research project between industry and academia. By developing the taxonomy we aimed to study how researchers and practitioners perceived the use of this type of taxonomy to support the industry-academia communication, how SERP-MENTION can be used to describe challenges in the industry and solutions in academia, and finally the potential of the developed taxonomy to link the solutions and challenges. We report our experiences from applying the SERP approach as well as the resulting taxonomy.

The outline of this paper is as follows. In Section 2 background and related research is presented, and in Section 3 the research methodology is presented. The results from the execution of the research are presented in Section 4 and then analyzed and discussed in Section 5, before the main conclusions are summarized in Section 6.

2 Background and related research

2.1 The SERP approach

Many taxonomies have been developed to structure and understand the area of software engineering. Usman et al. [26] conducted a mapping study on taxonomy development in software engineering based on 270 primary studies. They conclude that there is a strong interest in creating software engineering taxonomies but few are extended and maintained. Bayona-Oré et al. reviewed literature on methods and guidelines for taxonomy development and propose a generic method for taxonomy development within software engineering [6]. Petersen and Engström proposed the SERP taxonomy architecture [19] for taxonomies, aiming at supporting the matching of software engineering challenges and solutions in context. Engström et al. further developed and validated a taxonomy, SERP-test, based on the SERP taxonomy architechture, using the guidelines proposed by Bayona-Oré et al. [6]. SERP-test has then been extended with details specific for regression testing to support the search for industry relevant regression testing evidence [2]. In this paper the *SERP approach* refers to both the taxonomy structure as proposed by Petersen and Engström [19] and the process of taxonomy development and evolution as proposed by Bayona-Oré et al. [6].

A SERP taxonomy covers three facets for describing practical challenges: 1) desired effect, 2) context factors, and 3) scope of change. Research solutions are described by these three facets and one additional facet, 4) intervention. For each facet a taxonomy of entities are built bottom-up within a community of practitioners and researchers having interest in the topic. Important steps in the taxonomy development are the definition of the scope and purpose, identification of important terms, increments of validations and updates against its purpose, and deployment in the community of users.

2.2 Managing vulnerabilities in IoT

Here, we use the SERP taxonomy structure to develop a taxonomy in the area of vulnerability management in Internet of Things (IoT). A vulnerability is an externally reported problem in software that should be considered to be removed, otherwise the security of the software can be decreased [18]. The NVD CVE (National Vulnerability Database, Common Vulnerabilities and Exposures) database has an increasing number of vulnerabilities listed [18]. In 2017 only there were more than 14,000 new vulnerabilities reported. A large share of the vulnerabilities that are reported in the CVE database describe vulnerabilities in Open Source Software (OSS) components. Since IoT products often are based on OSS, vulnerability management is important in IoT system development and management [17]. Management of vulnerabilities denotes the actions taken to identify vulnerabilities in code, evaluating their criticality, making changes, and deploying new versions in operational code [12]. Since it is often costly to deploy changes in operational products in IoT the ability to identify and analyse vulnerabilities in a reliable way is crucial, not the least because of the large number of published vulnerabilities.

2.3 Taxonomies in IoT security

SERP-MENTION was developed to support the communication between industry and research, the purpose differs from other taxonomies developed in the area of security for IOT, a field where vulnerability management is included. Dosemain et al. [8] proposed a taxonomy to define the connected objects to IoT, identifying energy,communication, functional attributes, local user interface and hardware, and software resources. The possible threats and attacks for IoT have also been addressed by researchers through taxonomies, Babar et al. [5] classified the possible threats by the use of IoT, while Nawir et al. [16] identified the network security attacks. Finally, Adat et al. [1] identified security challenges and provided a taxonomy of defense mechanism in IoT.

3 Research methodology

The methodology used in this study share similarities with action research in that we designed a solution to a problem in one specific case. However, the solution, SERP-MENTION, was developed and evaluated off-line, in parallel with the project under study, which was an ongoing industry-academia research collaboration project, and unlike action research we did not change the studied case context based on the findings.

3.1 Research questions

The overall goal of the study is to investigate the application of the SERP approach in a new area, i.e., IoT vulnerability management. Thus the contribution is twofold: 1) the resulting taxonomy (SERP-MENTION) as such, developed to support communication between researchers and practitioners in IoT vulnerability management and 2) a validation of the SERP-approach. The research questions are as follows:

RQ1 To what extent can the SERP-taxonomy architecture be reused to develop a taxonomy in the area of IoT vulnerability management?

RQ2 To what extent is SERP-MENTION useful for improving the communication about vulnerability management between researchers and practitioners?

RQ3 To what extent is SERP-MENTION useful for linking research outputs and practical challenges?

To answer the first question we apply the SERP-approach to develop SERP- MENTION and reflect on the procedure. The second question is answered by conducting interviews and a workshop, and by applying the taxonomy to a sample set of research papers. The third question is answered by mapping practical challenges identified in the workshop and literature with research results identified in the literature.

3.2 Project under study

Since we are investigating industry-academia communication, our case under study is a research project involving both practitioners and researchers. The goal of the studied research project was to develop support for working with vulnerabilities in industrial IoT software development and maintenance. The project was executed in a time period of about 3 years and consisted of partners both from the university, industrial organizations working with software development, and an institute taking a role resembling that of universities. In total two university research groups, one research institute, and six industrial organizations were involved. The project was funded by a national funding agency and the industrial organizations participated with in-kind funding. In the project, support was developed both in the form of software tools, and in the form of a process improvement model for working with questions related to vulnerability management.

3.3 Research process

We followed the steps in Figure 1. The first version of the taxonomy was developed starting with the SERP-taxonomy architecture [19]. We reviewed a set of

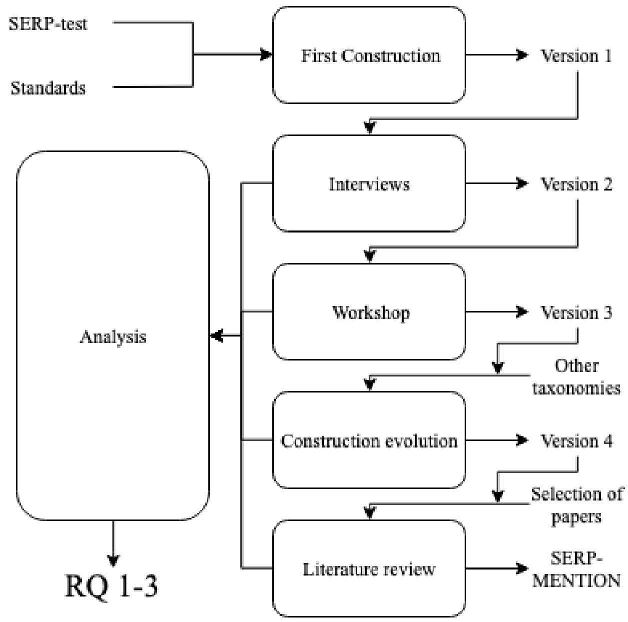

Figure 1: Research steps

standards, identified in a first literature search, and mapped the extracted requirements to the SERP-taxonomy architecture[1].

Two interviews were conducted with senior researchers who participated in the research project. The first interviewee is also the third author of this paper. The second senior researcher has more than 10 years of experience in cryptography and software security. The purpose of the interviews was to identify if the researchers recognized a communication gap in the project, to evaluate if the SERP approach seemed to be a way to bridge the gap and to evaluate the proposed taxonomy. The interviews were semi-structured with a set of questions formulated before the interviews. Questions covered the interviewees role and experience, foreseen challenges, comments about the current version of the taxonomy, expectations on the project, design decision during the project, and thoughts about possibilities and challenges when using the results of the project.

As the next step, a workshop was carried out with participants involved in the case research project. In total 9 people were involved, 4 persons from industry, 3 from academia, and 2 from research institutes. The workshop had two objectives, to analyze the usefulness of the taxonomy for describing challenges, and to identify entities that were lacking in the taxonomy. At the workshop we there-

[1]The interview and workshop protocol are available at http://doi.org/10.5281/zenodo.3234676

fore instructed the participants to carry out three activities. First they formulated improvement goals on the form "To achieve *effect* for *context* in *scope*" without using the taxonomy. Then they tried to rewrite them using entities provided in the taxonomy. This allowed us to compare the results. Finally, they were given the possibility to propose entities to the taxonomy that would have helped in specifying the challenges further. The feedback from the workshop was the main input for the third version of SERP-MENTION. After the workshop we incorporated entities from taxonomies identified in related work, see Section 2.3.

Finally, in the last phase the generality of the taxonomy was evaluated by using it to describe challenges and solutions derived from a sample set of academic papers. The papers were retrieved doing a one-level snowballing, taking as seed three prior papers produced in the research project (papers [7, 12, 17]). This resulted in the final version of the taxonomy. The set of challenges and solution derived from literature was then mapped to the challenges derived from the workshop based on the final version of SERP-MENTION to evaluate the ability of the taxonomy to link research outputs with real challenges, which is one of the purposes of a SERP taxonomy.

3.4 Limitations

In addition to constructing a SERP taxonomy for vulnerability management we have collected and analyzed data, from one industry-academia collaboration, about the approach as such, through interviews, a workshop and a literature review. Trustworthiness of this type of qualitative research can be assessed not only in terms of validity, but also in terms of generalizability and reliability [21].

Generalizability As this is a single study, we cannot draw any general conclusions about the SERP approach from this study alone. However, as a complement to previous and future studies on the SERP approach, it can provide support for its value. We support theoretical generalization by providing relevant details about the context and nature of project under study. The generality of the taxonomy as such, i.e., SERP-MENTION, was evaluated by applying it to a sample set of papers. Although this evaluation confirms that the taxonomy applies also to challenges and solution extracted in other contexts than our studied project, it does not confirm general completeness. This means that the structure of the classified entities may be reused as is, and in addition new entities may be added to the taxonomy as the identification of practical challenges and relevant research solutions emerges. To get a complete overview over the research on vulnerability management, a full systematic literature review is needed.

Validity To strengthen the validity of our conclusions we have applied a systematic procedure for collecting and analyzing the data, and we have been careful not to overgeneralize our findings. One threat to the validity is researcher bias, since the second author of this paper had developed similar taxonomies before and the third author was involved in the studied industry-academia collaboration project, and was also one of the interviewees. This threat was mitigated by letting the first author lead the taxonomy construction process as well as the design of the interviews and the workshop and analysis of the data. All three authors were involved in validating the outcome of each step.

The conclusions drawn about the usefulness of the taxonomy is based on participants perceptions and indirect evidence regarding aspects of using the taxonomy that could be tested off-line, e.g. improved preciseness of challenge descriptions.

Reliability The reliability of the results refers to the consistency of interpretations of terms and concepts. This is strengthened by the fact that researchers were familiar with the tool (SERP) as well as the project under study. However, none of the researchers were experts on vulnerability management, which may have negative impact on the validity of the taxonomy. This is mitigated in accordance with the taxonomy development process [6] by involving domain experts in the development and evaluation of the taxonomy.

4 Results

4.1 Interview results

In the first interview, the researcher described the evolution in the project, starting from a potential need identified by researchers to the implementation of a tool that was used by industrial companies. The tool identifies and evaluates vulnerabilities in OSS components used in IoT systems. For the tool development, collaboration between researchers and practitioners was required. That is one reason why a common understanding about the objectives and the way of working of the tool was needed. Related to the communication gap, the researcher pointed out how the awareness, concerns, and challenges about security were different for each company, according to their size, culture, maturity, and type of product or service offered. However, the need to handle vulnerabilities was relevant for all the companies, which meant that communication was essential to understand needs and context in the project in order to develop a useful tool. The interviewee was asked to describe challenges related to IoT security, with and without the first version of SERP-MENTION. The preliminary result after the exercise was that using SERP-MENTION can improve the precision and clarity of the challenge descriptions.

The second interview followed the same questions and there were no disagreements, but some additional aspects were discussed. Given that the second interviewee is an expert in information security one purpose was to evaluate the scope and categories of the taxonomy. The main scope of IoT vulnerability management was confirmed by the researcher as an interesting topic in academia, and also as relevant to companies according to the interviewee's previous experiences with industry.

The facets were analyzed and some changes were made. The effect facet was refined, deleting entities that were out of scope, too general or actually described activities instead of desired effects. The scope was limited to include only activities related to vulnerability management instead of the whole IoT product cycle.

4.2 Workshop results

Workshop participants described practical challenges related to IoT vulnerability management. In the analysis, challenges were classified into three groups A, B, and C, according to how well they followed the taxonomy after the second task, i.e., when they were asked to rewrite the challenges based on the taxonomy; A for correctly following the taxonomy, B for partial adherence, and C for those who did not follow it at all.

After the second task, it was clear that challenges in groups A and B were better than those in group C. A better description means that the desired effect, context and scope were more specific with less internal terminology. It was clear that the challenges described in group C were still too general. The challenges in group C also used words related to specific companies, which makes them more difficult for others to understand. Table 1 shows the A and B challenges described by the workshop participants.

Concerning the terminology used to describe the challenges, the terms from the effect facet were utilized, new terms suggested by the participants were added to the taxonomy in relation to efficiency and trust. From the context facet, just a few terms were used, while around half of the scope facet were used. Challenges from groups B and C mixed terms from the scope and the context, some participants described "the company" or "our project" to describe the scope. These inputs were taken into account for the new version of the taxonomy. For example, the entities of the scope facet were reduced to only cover the vulnerability management process and new entities were added to the other two facets.

For example, one challenge was formulated as "to achieve faster CVE evaluation during the software development for the project" before using the taxonomy, and as "to achieve quicker and more accurate vulnerabilities management during the product design for the organization" after using the taxonomy.

4.3 Literature review

To evaluate the generality of the taxonomy we applied it to a sample of relevant papers. As described in Section 3.3, the sample papers was derived as the relevant references of the papers produced in the case project. Examples of non-relevant

Table 1: Challenges described by the Workshop participants

Entry	Challenge Description
Ch1	To improve the communication with clients and partners.
Ch2	To improve the speed of decisions about vulnerabilities.
Ch3	To diagnose the importance of identified vulnerabilities.
Ch4	To automatically identify vulnerabilities.
Ch5	To improve the time to patch vulnerabilities.
Ch6	To improve the time to respond to vulnerabilities.
Ch7	To improve the efficiency in evaluating vulnerabilities .
Ch8	To improve the accuracy of the vulnerabilities evaluated.
Ch9	To define a process to handle vulnerabilities.
Ch10	To determine the need for urgency of the response.
Ch11	To more promptly address identified vulnerabilities.
Ch12	To achieve lower cost for identified vulnerabilities in the product life cycle.
Ch13	To achieve higher credibility for the company brand in the user community.

paper are research methodology papers and papers about cyber-security in general, e.g,. discussing specific vulnerabilities that have been found in products.

From the literature we derived an additional set of challenge-descriptions as well as a set of solution proposals. These are listed in Table 2. Table 3 shows the final taxonomy, grey marked, and the mapping of challenges and solutions derived from the workshop and the literature.

The purpose of this evaluation was to ensure that all entities and categories of the taxonomy had counterparts in real research outputs or challenge descriptions related to the project under study. For a taxonomy to be used it should be aligned with the terminology used by the intended users, in our case researchers and practitioners in IoT vulnerability management.

In this exercise we could see that all categories below level 3 for all facets but 'intervention' was useful and sufficient, as all categories were mapped to at least one of the challenges or solutions, and that no additional categories were needed at that level to classify the entries. However, the taxonomy at that stage also included entities at higher levels of detail that were not fully covered. Categories or entities that were not covered by any challenges or solutions extracted from literature or the workshop were removed from the taxonomy.

In summary, our literature review and mapping confirmed stability of parts of the taxonomy as shown in Table 3 and indicated a mismatch between the literature, standards and industrial needs regarding the details. This mismatch would require an extensive systematic literature review to be proven and understood, which is out of the scope for our study. The taxonomy proposed here may however guide such review.

Table 2: Practical challenges and research solutions derived from the selected papers in the literature review

Src	Entry	Entry Description
[13]	Ch14	To prevent the intruder's access to the objects that may cause physical damage or change their operation.
	Ch15	To assure security measures for the transmitted data from devices and prevent it from external interference or monitoring
	Ch16	To guarantee the data integrity at the information processing unit
[22]	Ch17	To attestate efficiently in a large dynamic and heterogeneous network.
[23]	Ch18	To evaluate identified vulnerabilities to identify relevance and impact.
[12]	Ch19	To identify relevant vulnerabilities among the huge amount of information about vulnerabilities.
	Ch20	To evaluate identified vulnerabilities to identify relevance and impact.
[4]	Ch21	Developers perceive system availability more important than confidentiality.
[24]	Sol1	To improve the Instruction Detection Systems, SecAMI calculates a relationship between attack spreads, detection, and consequences on the availability.
[13]	Sol2	To be able to identify potential vulnerabilities, in any company developing IoT systems with OSS, track versions of used OSS or COTS versions in the products.
	Sol3	To facilitate correctness in the evaluation of vulnerabilities in in any company developing IoT systems with OSS, track possible threats in software products.
	Sol4	To achieve faster and more robust management of vulnerabilities in any company developing IoT systems with OSS, have a well defined process for identifying and monitoring sources of vulnerabilities.
	Sol5	To achieve a more cost efficient remediation of vulnerabilities in any company developing IoT systems with OSS, evaluate severity and relevance of vulnerabilities and make decisions for handling and reacting to identified vulnerabilities.
	Sol6	To allow a more robust and transparent vulnerability process in any company developing IoT systems with OSS, communicate vulnerability and security information, internally and externally in a structured way.
	Sol7	To improve transparency, effectiveness and awareness of the vulnerability management process in any company developing IoT systems with OSS, use HAVOSS.
[3]	Sol8	To increase the vendor's patch release speed, disclose vulnerability information.
[14]	Sol9	To diagnose the importance of vulnerabilities, evaluate with respect to the CVSS score.
[11]	Sol10	To identify vulnerabilities automatically, apply fuzzing and penetration testing.
	Sol11	To detect overflows, follow a combination of automatic approaches.
	Sol12	To improve effectiveness of vulnerability, use code review.
	Sol13	To respond quickly, vulnerabilities should be reported to companies.
	Sol14	To improve reputation, companies should respond more quickly to reported vulnerabilities.
[7]	Sol15	To improve effectiveness and efficiency of the of vulnerability identification and assessment in any company developing IoT systems with OSS, use the tool for mapping vulnerabilities to code.

4.4 SERP-MENTION

In this subsection, we present SERP-MENTION. As described in Section 3, the taxonomy was developed incrementally. Here the fifth and latest version is presented. SERP-MENTION enables classification of research results and practical challenges in IoT vulnerability management. Each entry can be described and classified using the facet-based SERP architecture [19].

Table 3: Mapping of challenges and solutions to SERP-MENTION

	Effect													Scope						Context										Intervention	SERP -MENTION
	Improve										Solve		Diagnose							People	IoT system						Business				
	Access control	Secure data communication	Resilience to attacks	Availability	Process transparency	Process effectiveness	Process efficiency	Vendor's patch release speed	Awareness of security	Trust	Define vulnerability process	Automatic identification	Importance of vulnerabilities	Identification	Communication	Patch management	Assessment	Configuration management	Design-Development	Development culture	Objects spread geographically	Large number of objects	Lighweight encryption	Heterogeneus networks	Solaris	Open sorce software	Lack of resoruces	Open business environment	Vendors		
Sol1			✓											✓							✓									Use the risk assessment tool SecAMI	Mapping
Sol2											✓			✓												✓				Track versions of used OSS or COTS	
Sol3						✓											✓									✓				Track possible threats in software products	
Sol4						✓	✓							✓	✓		✓	✓								✓				Have process for identifying and monitoring sources of vulnerabilities	
Sol5							✓										✓									✓				Evaluate severity and relevance of vulnerabilities and make decisions for handling and reacting	
Sol6					✓	✓								✓		✓	✓									✓				Communicate vulnerability and security information, internally and externally	
Sol15					✓	✓			✓					✓	✓	✓	✓	✓	✓							✓				Use HAVOSS	
Sol8								✓								✓													✓	Disclose vulnerability information	
Sol9													✓				✓													Evauate with respect to the CVSS score	
Sol10												✓		✓																Apply fuzzing and penetration testing	
Sol11						✓								✓																Folllow a combination of automatic approaches.	
Sol12						✓								✓																Use code review.	
Sol13					✓										✓													✓		Vulnerabilities should be reported to companies.	
Sol14										✓						✓												✓		Respond more quickly to reported vulnerabilities	
Sol15						✓	✓							✓			✓									✓				Use the vulnerability tool by Cableigh et al. for mapping vulnerabilities to code.	
Ch1										✓						✓										✓					
Ch2							✓							✓	✓	✓	✓	✓	✓							✓					
Ch3													✓				✓									✓					
Ch4												✓		✓												✓					
Ch5							✓									✓										✓					
Ch6							✓							✓	✓	✓	✓	✓	✓							✓					
Ch7						✓											✓									✓					
Ch8						✓											✓									✓					
Ch9											✓															✓					
Ch10											✓						✓									✓					
Ch11							✓							✓	✓	✓	✓	✓	✓							✓					
Ch12							✓							✓												✓					
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Ch16	✓															✓							✓								
Ch17	✓																		✓					✓							
Ch18				✓															✓						✓						
Ch19				✓										✓													✓				
Ch20				✓													✓										✓				
Ch21									✓										✓	✓											

The main facets of the taxonomy are *intervention*, *effect*, *scope* and *context*. Each SERP facet is the root of a taxonomy of entities grouped in categories (or nodes). The first and second level of each such category are visible in Table 3. SERP *entries* refer to descriptions of practical challenges or research outputs on a format including *entities* from the SERP facets. Research results can for example be expressed like:

> To achieve *effect* during *scope* in *context* do *intervention*.

Challenges are expressed in a similar way but do not include an entity from the intervention facet. An example of a practical challenge is:

> It is a challenge to *improve the efficiency* of the *vulnerability evaluation* when *OSS is used in the IoT system*.

An example of a research result [25] is:

> To *improve the access control* during *the patch management*, when *having a large number of objects*, do *implement a security manager on top of the centralized IoT hub*.

Intervention

An intervention is an act performed, to diagnose, solve a problem or improve vulnerability management. The interventions listed in Table 3 were extracted from the research proposals in our literature review. We did not find it meaningful to categorize this list further. For SERP-MENTION version 1, we added categories based on requirements derived from the IoT security standards such as: "provide automated support" and "secure design". However, during the literature review and mapping, we found that this classification was not useful as it did not match the extracted interventions nor was it orthogonal.

Effect

An effect is a target, i.e. what is to be achieved by an intervention. Inspired by SERP-test [9], we identified three relevant types of effects: *improve, solve,* and *diagnose*, where improve refers to measurable improvements of the current state.Solve refers on the other hand to a request for solutions to unsolved problem, e.g. no current solution exist to compare with. Finally, diagnose refers to requests for support in assessing the current situation We identified 10 improvement goals, 2 unsolved problems and 1 diagnose target, listed in Table 3.

Scope

The scope entities in SERP-MENTION are activities of the vulnerability management process. For a solution, it refers to the activity where the intervention is applied, while for a challenge it refers to the activity for which the effect is desired. We identified 6 such activities, listed in Table 3. *Design and development* are activities carried out before the IoT system is deployed; *vulnerability identification*, *assessment* and *patch management* after the IoT system is deployed; and *communication* with customers, partners, etc. along the whole process.

Context

The context entities are factors that either motivate the need for an intervention or affect the applicability and effect an intervention, e.g, the use of open source code when IoT products are developed. The context factors extracted in this study are categorized to be either *people*-related, *business*-related, or *system*-related. People factors are related to humans like the culture in the company. Business factors are constraints given by the business environment or business decisions. System factors are related to the nature of the IoT systems. We identified one people-related factor, five system-related factors and four business-related factors, listed in Table 3.

5 Discussion

IoT is an emergent topic both in industry and academia. An indication of this is the IoT ecosystem fragmentation and a lack of standards [15]. When a new terminology is starting to be established, taxonomies are useful. They allow to reason about classes of problems instead of specific instances. They can also support communication by providing concepts and a technical language [20]. In this research this was seen, e.g., when participants listed challenges. Even though they had experience and knowledge about security they lacked a common terminology.

To cover the needed terminology, SERP-MENTION was developed with focus on vulnerability management. We considered both the technical, methodological and organizational dimensions of IoT vulnerability management. When reviewing existing taxonomies for IoT security [1, 5, 8, 16] (Section 2.2), we found that they were partly useful also for our purposes. and thus we decided use some of their categories to structure the facets in the SERP-MENTION. SERP-MENTION can be reused and adapted, adding more categories and entities to the facets, also parts of other taxonomies can be included. A key difference between SERP-MENTION and previous taxonomies is that SERP-MENTION is designed to support communication between researches and practitioners by providing a way to link challenges from industry to solutions in academia while the other taxonomies were focused in describing or gain understanding about specific IoT security topics.

SERP-MENTION was developed in the context of an industry-academia collaboration project. The need for this type of taxonomy was identified, at least by the researchers, in the project and it was developed in parallel with the project. The final version of the taxonomy as presented in this paper was completed in the end of the collaboration project and thus not explicitly used in the project. However, in retrospect the usage of this type of taxonomy in the project had it already been developed could probably have helped especially researchers to get a more complete understanding of important research questions. Furthermore, in presenting results, a taxonomy like this could probably be useful as a guide, not the least in communication in academic articles. It would probably also have given a richer and more consistent terminology in communication within the project.

SERP-test is another SERP taxonomy, also aimed to support the communication between researchers and practitioners but in the area of software testing [9]. Both similarities and differences are observed. In both cases the scope seems to be the facet with the highest agreement between how industrial need and research results are communicated. Similarly, in both cases the intervention facet remains unrefined as it is hard to find a general and orthogonal classification of interventions. This facet is not needed for matching purposes, but could be useful for comparing several solutions to the same challenges. An example of how this is done for a special case of testing, regression testing, is provided in a systematic literature by bin Ali et al. [2]. The first two levels of the 'effect target' is identical with the first two levels of SERP-test, but there is more variation in the details. The case is similar when it comes to context factors.

To develop taxonomies in software engineering Bayona-Oré et al. [6] have proposed a method and Usman et al. [26] reviewed that method suggesting some improvements. The method considers the phases of planning, identification, and extraction, design and construction, validation, and deployment. In the development of SERP-MENTION we followed the phases of the method: Planning is part of the research steps, the design and construction approach was incremental, where for each increment activities of identification and extraction were developed. The validation of the taxonomy was carried out in the literature review and the mapping of the entries to be classified.

A taxonomy can be developed top-down or bottom-up. While developing SERP-MENTION we combined the two approaches. The top-down approach was followed when we started from SERP architecture, reviewing standards, and reusing taxonomies. The bottom-up approach while adding entities that were actually used when describing challenges and solutions in the workshop and reviewed literature.

6 Conclusions

A contribution of this study is SERP-MENTION, see Sec 4.4, a taxonomy developed to support communication between industry and academia in IoT vulnerability management by enabling holistic, precise and unified descriptions of practical challenges and research outputs. By developing SERP-MENTION we can reflect on the usefulness of the SERP architecture for this purpose (RQ1). SERP-MENTION shares the four main facets with the SERP architecture (intervention, effect, scope, and context). SERP architecture also allows integrating other taxonomies partially or completely to describe a specific facet.

A mapping between research and practice is useful in several phases of a research project: Initially, in a collaborative research project, SERP-MENTION can be used to support expressing the challenges (or research questions) in a precise and holistic way and to ensure that everyone involved have a shared understanding of the problem to solve. Further it may guide a search for relevant literature and when reporting results it ensures that this is done consistently with other practitioners and researchers in the community.

The participants in the project, both from industry and academia, were during the workshop able to describe challenges using the taxonomy, in a more precise way than without. This is a first indication of the usefulness of the taxonomy to improve the communication in the project (RQ2), although further research is needed.

During the literature review we mapped, using SERP-MENTION, the research results identified in the literature and the industrial challenges derived from the workshop. The mapping helped to validate the developed taxonomy. Furthermore, it shows the potential of SERP-MENTION to link research and practice or, in case such links are missing, to visualize a gap between research and practice (RQ3).

Finally, we share some reflections about the development method. An incremental method helped us to quickly incorporate feedback from the previous steps. A combination of approaches, top-down and bottom-up was useful to map and validate the taxonomy. Involving practitioners in the development process contributed to giving the taxonomy practical relevance.

SERP-MENTION is not complete but mirrors the main aspect of the research project under study and its related research literature. It may be used as is or extended in other projects with similar scope.

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CHAPTER II

A CASE STUDY OF INDUSTRY-ACADEMIA COMMUNICATION IN A JOINT SOFTWARE ENGINEERING RESEARCH PROJECT

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Abstract

Empirical Software Engineering research relies on good communication with industrial partners. Conducting joint research is one way of bridging the communication gap between industry and academia in software engineering. This study aims to explore communication between the two parties in such a setting. To better understand what facilitates good industry-academia (IA) communication and what project outcomes such communication promotes, we performed a case study, in the context of a long-term IA joint project, followed by a validating survey, among practitioners and researchers with experience of working in similar settings. We identified five facilitators of communication and nine related project outcomes. The facilitators concern the relevance of the research, practitioners' attitude and involvement in research, frequency of communication and longevity of the collaboration. The project outcomes promoted by this communication include, for researchers, changes in teaching and new scientific venues, and for practitioners, increased awareness, changes to practice, and new tools and source code. Besides, both parties gain new knowledge and develop social-networks through IA communication. Our study presents empirically-based insights that can provide advise on

how to improve communication in IA research projects and thus the co-creation of Software Engineering knowledge that is anchored in both practice and research.

1 Introduction

Companies developing software, or software-intensive products and services, constantly strive to acquire software engineering competence to stay competitive. This involves getting access to people with relevant competence and developing the current knowledge within the company. Universities aim to be a source for both aspects of competence through graduating software engineers that can be employed in industry, and by conducting academic research that may add to the existing knowledge in the industry and contribute to improved industrial practices. Although the interplay between academic research and industry has been recognised as a way to exchange knowledge and innovate [2], little is known about how to manage mutual expectations and interaction [19]. Particularly in applied research disciplines like software engineering, the degree of interaction with industry is expected to be high as the research cannot be conducted in isolation in a university lab, but has to be – at least partially – conducted in real-world settings. Joint research projects, therefore, may provide mutual benefits for industry and academia. While industry gets access to competence, researchers gain insight into and access to real-world settings for their research [3].

Despite these potential mutual benefits, researchers have identified challenges in connecting research and practice [10]. The research topic and outcomes need to be relevant for industry [6, 9]. Research results should present practical advice to software engineering practitioners [15]. Different time perspectives and incentives may be conflicting [22]. Industry and academia have to develop a symbiotic relationship to bridge the gap between the two [3].

Our research goal is to understand, within the context of an Industry-Academia (IA) joint project, what facilitates good IA communication and what beneficial outcomes good IA communication may contribute to. By *communication* we refer to the exchange of information between people, including verbal, written and visual information, and in what context this communication takes place. Further, we acknowledge that information is different from knowledge, implying that communication is a means to promote outcomes of an IA joint project, not a goal in itself. However, we hypothesise that communication is indeed an important factor for IA joint projects.

Throughout an IA research project researchers and practitioners communicate in different contexts and for different purposes [11]. Before officially starting a project, the discussions are usually focused on selecting the research topic and building the team. Once the project starts, the participants jointly define the project plan. During the operation of the project, two types of communication take place, one is related to the research work where researchers collect empirical data, and practitioners get involved in the research process. Another type is about the management and follows up of the project. Finally, the knowledge is encapsulated in scientific publications and solutions for industry. By studying the communication between researchers and practitioners, we aim to gain knowledge on how to manage communication in future IA projects.

In this study, we investigate the following research questions:

RQ1 What characteristics of a joint project facilitate IA communication?

RQ2 What outcomes of a research project can good IA communication promote?

We conducted a case study of an IA joint project to answer these question. We explored the characteristics and outcomes of the communication within our case project, and validated our findings through a survey. As our case, we studied a 3-year project within a 10-year research program including three companies and two academic partners. Our main data collection consisted of a project retrospective that was conducted using a time-line based method [4] at the closing stage of the research program. The retrospective was conducted as a focus group meeting using a time-line as a catalyst for the data collection. The time-line visualised key events within the project and was prepared before the meeting. The audio recording from the focus group meeting was transcribed, coded, and thematically analysed in line with our research questions. Later, the results from the analysis were validated through a survey with a broader population. The survey was based on the communication facilitators and related project outcomes identified in the case study.

The main contributions of this paper are twofold. Firstly, we explore the role of IA communication within a joint research project and what characteristics of the project that facilitated this communication. Secondly, we identify some outcomes of the IA joint project that were promoted by the IA communication within the project.

We describe related work in Section 2 and our case study in Section 3, including the case and research method. Our results from the case study and the validation survey are presented in Section 4 and discussed in Section 5. Finally, Section 6 concludes the paper.

2 Background and Related Work

Researchers across disciplines have investigated IA joint work from different perspectives. One example is a review published by Salter et al. [24], where the authors investigated the economic impact of public-funded research. The authors identified six types of contribution to economic growth related to the extension of useful knowledge, training of graduates, new scientific methods, networks and social interaction, increased scientific and technological problem solving, and new companies. From an organisational perspective, Good et al. conducted a literature review around technology transfer ecosystem [13], i.e. university-affiliated organisations that are involved in technology transfer activities. Specifically, the authors analysed technology transfer offices, science parks, incubators, and university venue funds. The authors concluded that those terms have been studied in isolation and highlighted the need for a holistic approach. In another review, published by Perkmann and Walsh, the topic is the interaction channels between industry and academia and the contribution to open innovation [19]. Joint research projects like the one in this case study are identified as one of the IA links, named research partnerships. Other links are research services, commercialisation of property rights and people exchange. One relevant finding for this research is that research around joint IA work has been focused more on the effects of the joint work and less in how this joint work is done.

Among the research about how industry and academia work together, communication has been identified as an essential factor. Ankrah and Al-Tabbaa [2] conducted a systematic review of 109 papers on university-industry collaboration across different research disciplines. They present a model covering motivations to collaborate, how the collaboration is formed and operated, the factors that enhance and inhibit the joint work, and the outcomes. The model includes communication in two ways: as a key factor in the inter-organisational relationship and as activities that take place throughout the joint work.

Similarly, from a source of 103 papers about industry-university collaborations Rybnicek and Königsgruber [23] recognise the importance of communication as a factor that influences the relationship. They started their analysis based on the facilitating factors for IA collaboration identified by Ankrah and Al-Tabbaa [2] and identified the following facilitating factors of communication: frequency of communication; degree of personal relationships both at the management and operational level; degree of regular interaction; continuous feedback; the variety of communication channels; and the existence of a common 'language' suitable for both parties. Under the area of 'culture', they also identify factors related to communication, such as how to handle gaps between industry and universities, and acknowledgement of different terminology in other organisations.

In software engineering, Garousi et al. [10] conducted a systematic literature review on IA collaborations, with a final set of 33 primary studies. The authors identified challenges and best practices in IA collaboration. They adopted the model proposed by Ankrah and Al-Tabbaa [2]. Challenges related to communication were identified all around the life-cycle. Some of the challenges related to communication included gaps in time horizon, areas of interest, and responsibilities; difficulties at handling multiple collaborators; lack of standard terminologies; and low pre-existent networks before the projects.

In a follow-up study, Garousi et al. [11] surveyed 64 respondents around the world and identified which of the challenges and patterns identified in their previous study that impacted the projects described by the respondents (101 projects).

The authors found a high impact of challenges related to mismatch between industry and academia, human and organisational challenges and lack or drop of interest/commitment, and less impact of communication-related challenges. Notice that for communication challenges here, the authors limited to operational issues during the execution of the project, e.g., problems with Skype or dealing with several partners.

Researchers have investigated and proposed models related to IA joint work in software engineering. Sandberg et al. [25] presented a relational model that includes ten principles for managing IA collaborations. The model is based on research on collaborative practices [17]. Marijan and Gotlieb [16] presented the Certus model to reflect IA knowledge co-creation. The model relies on the idea that research needs to be done jointly by researchers and practitioners, and that this requires continuous dialogue and alignment between the participants. Similarly, Mikkonen et al. [18] published a model describing continuous and collaborative technology development. Their model supports the idea that innovation is not developed in academia and transferred to industry. Instead, it is joint work between industry and academia that leads to innovation. The first two models were derived from research programs similar to the one in our case study, one in Sweden and one in Norway, and the third from a national research program in Finland. Although these models do not explicitly model IA communication, they model IA joint work, which we believe relies on and creates IA communication.

Wohlin et al. [26] surveyed industry and academia representatives in Sweden and Australia about success factors for collaboration in software engineering. Having support from top management and a champion (contact person) on the industry site were considered the top factors for success, both by industry and academia respondents. Communication factors were not ranked explicitly (except for "regular meetings"), but they are inherent in several of the involved factors.

In summary, it can be seen that communication is identified as one important factor in IA joint projects. However, there are very few studies explicitly investigating IA communication.

3 Research Method

The research was conducted in two main phases with a total of six steps, as outlined in Table 1. In the first phase, a case study was carried out in the context of a joint IA research project. That project involved both researchers and practitioners. In the second phase of our study, we conducted a survey to validate the findings from the case study. This survey was conducted with a broader set of participants than included in the case study.

Table 1: Overview research methodology

Phase	Step	Result	Sample set
Case study	EBTR retrospective	Transcripts, timeline data	EASE project
	Coding	Coding scheme, coded transcripts	
	Analysis	Facilitating factors, outcomes	
	Member checking	Initially validated facilitating factors and outcomes	
Survey	Electronic survey	Survey responses	Regional organisations
	Analysis	Elaborated facilitating factors and outcomes	

3.1 Case study

The objective of the case study was to investigate our research questions, i.e. to identify factors that can facilitate IA communication and outcomes promoted by good IA communication in a joint project. As our research goal was to investigate this type of complex phenomenon, we identified a case study as a suitable choice of research method [21]. Studying a specific case allows us to gain in-depth insight into communication. The unit of analysis is a research project, as described in the following Section.

Case Description

The case study was conducted within The Industrial Excellence Centre for Embedded Applications Software Engineering, EASE – a 10-year research program performed 2008–2018 in close collaboration with industry. The program involved two academic partners and three industrial partners. The budget comprised 10.5 MSEK ($\approx$ 1 M€ or 10 full-time equivalents) per year, and was jointly funded by industry (50%), academia (33%), and a national innovation agency (Vinnova) (17%). The overall goals of the program were threefold:

i) Availability of competent personnel,

ii) Making results useful for industry, and

iii) Research excellence.

While these goals on the surface may be considered contradictory, industry and academia partners agreed on that they were fully compatible through the conduct of applied software engineering research, published in highly ranked publication outlets.

The research program included three to four projects in parallel, organised around different topics in software engineering. A board of directors, composed of representatives for the funding organisations, made the decisions on which themes to explore, and the budget for each project. Within the program, PhD students, postdocs, and faculty were funded to a varying degree throughout the program. M.Sc. student projects were also executed within the program, although financed by separate sources. Decisions about the acceptance of new PhD students into the program were taken at the program board level, while at the project level, specific research activities were decided. Parts of the industry contributions were in kind, with industry employees working in, and interfacing with the research program.

The collaboration practices during the setup phase of the program are previously published [20], while we herein focus on a specific project executed during the last three years of the program. The joint projects executed during the last three years had the following themes[1]:

- A. Configuration and interaction in Internet-of-Things
- B. Parallel execution for embedded systems using machine learning
- E. Increased efficiency in software development through decision-support in the testing process

For each of the projects in the program, a reference group was set up with one or more representatives from each company involved in the specific project. The reference groups met regularly with the researchers within the project to share progress reports and discuss further research. Once a year, a two-day conference was held off-site to report progress across the program and to discuss and plan the research in more depth. In addition to these management meetings, industry and academia representatives met to work on developing research prototypes, for interviews and empirical observations, and planning purposes. In total, 500 IA meetings were recorded during the 10-year duration of the program, eight PhD thesis were examined, and more than 200 scientific papers were published.

In this case study, we investigate one of the joint projects that was active during the final three years of the program. This project focused on increased efficiency in software development through decision-support in the testing process. The project group consisted of 6-13 researchers and 3-5 practitioners, where most of the senior researchers had been involved in a previous project within the same program. The high proportion of academics is due to an increase in the number of PhD students. Over the duration of the project, PhD students and faculty members funded by other projects participated in the activities of the case study project; thereby the varying number of participants. Research activities in this project included literature studies and synthesis, problem conceptualisation through interviews and observations, development of solutions, and evaluation of solutions in context. Projects conducted by faculty, postdocs and M.Sc. students could have shorter time perspective (a couple of months) while PhD student projects need a longer perspective to fit into the thesis work. However, studies within the frame of PhD student projects may have shorter timelines.

Research results from the case project include systematic literature reviews (one of which included a perspective that was particularly relevant to industry, namely industrially evaluated regression testing methods [1]), practical guidance

[1] The enumeration scheme comes from projects C and D of phase 2 being merged into project E.

to industry on specific software engineering methods, for example, test scoping [8], automated bug assignment [14], and exploratory testing [12], and theory to explain and improve communication within software engineering [5]. Some articles were published in practitioner-oriented magazines, while most papers were published in high-ranked journals and conferences. One of the sub-projects is presented by Carver and Prikladnicki [7] as an example of a successful IA collaboration in software engineering. Regularly, researchers were invited to companies to present their results, or practitioners were invited to the universities for seminars.

Data Collection through Retrospectives

In the first step of the case study, data collection was conducted as a retrospective meeting, using a method based on evidence-based timelines called EBTR [4] that facilitated reflecting on how industry and academia had worked together within the research program. Evidence-based timelines were constructed prior to the retrospective meeting from available project data (evidence) to provide a visualisation of the project history. In the retrospective meeting, these timelines supported the participants in remembering past project events, and thus triggered and enabled a fact-based discussion guided by pre-defined focus questions. Through specifying goals and detailing these into focus questions and data to include on the timelines, the EBTR method enabled designing the retrospective to focus on specific areas or topics. In this case, the retrospective's overall goal was to understand the value of the IA partnership by exploring how joint work was performed within the research program and what benefits that had been gained both short and long term. Since this included considering who and how the work had been performed in the project, the material allowed us to study the communication between industry and academic partners in the context of the project and connected to the outcomes and benefits of that project.

Half-day retrospective meetings were held for each of the three projects active in the final phase of the program (see previous section). The retrospectives were first prepared, and then held with project members attending a program event. The goals for the retrospectives were to discuss the outcomes of the project for industry and for academia, how the joint work was done, e.g. who was involved and at what events did people communicate, and improvement opportunities. These goals were agreed with the board of the research program. As prescribed by the EBTR method, the retrospective was designed in-line with the agreed goals by pre-constructing timelines and focus questions to stimulate and guide the retrospective meeting. The timelines were prepared by the second author based on accessible data from, e.g., publication lists, lists of events, project reports etc., and by asking key project members, e.g. through meetings and email for additional data. Prior to the meeting, three timelines (people, interaction events and outcomes) contained the following information: the main participating persons as identified through project reports (people), the main meetings and events were entered as extracted from project reports and meeting notes (interaction events), the publications were included as identified through the university's internal publication databases (outcomes). A fourth timeline (needs and activities) was populated during the meeting as part of the retrospective discussions.

During the retrospective meeting, the participants were presented with the partly populated timelines printed on 2 x 1 m cloth, placed on a large table around which the participants gathered, see Figures 1 and 2.The retrospective participants worked for about three hours, analysing and discussing the research project based on the timelines and guided by pre-prepared questions. At the meeting, the work alternated between individual reflection and group discussions. During the meeting, the participants populated the timelines with more details, and when necessary, corrected or adjusted pre-printed timeline data. All project members, past and present, were invited to the retrospective meeting, and for the project reported in this paper, there were eight participants from academia and three participants from industry. One of the academics acted as the moderator and led the retrospective meeting. The moderator also ensured that both the industry and the academia perspective were equally voiced during the meeting, although they were imbalanced in numbers. The industry participants had all been actively involved in the project under study, and all played an active role throughout the retrospective meeting. Among the academic participants, all had been involved in the project to varying degrees, and their active participation to the retrospective varied with the extent of their involvement in the project. Three to four of the academic participants were active in research studies, while the rest were involved as supervisors and in various managerial roles, thus boosting the number of academic participants.

Figure 1: Discussions around the timelines (placed on the table) at the retrospective meeting with case project.

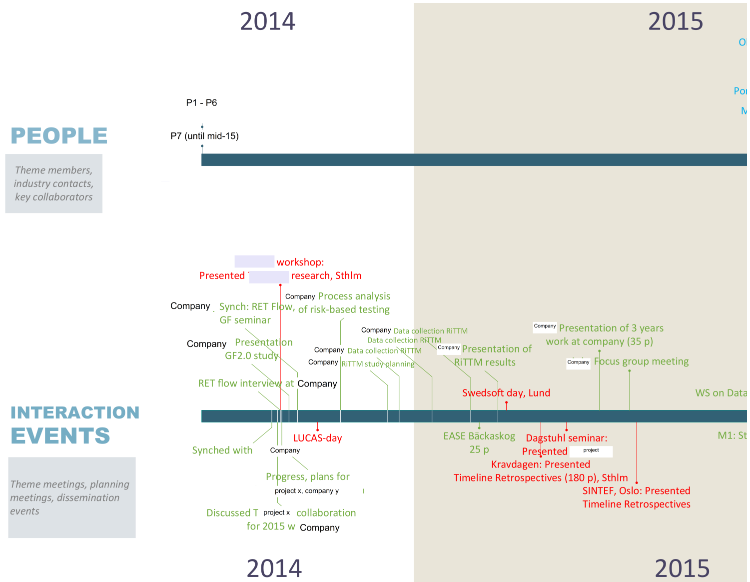

Figure 2: Example of a minor part of the timelines used at the retrospective meeting (anonymized for confidentiality).

The meeting was recorded using both video and audio, and notes were made on the timelines. After the meeting, the audio files were transcribed word-by-word by a professional transcriber. That is, the results of this stage consist of transcribed material from the retrospective meeting, and of timeline data extracted from project documentation and through the retrospective meeting.

Coding

The transcripts were imported into QSR International's NVivo 12 qualitative data analysis software for coding and analysis. Coding was conducted in two steps. Initially, four researchers (authors 1–4) read through the material and independently identified themes and proposed codes. The initial codes were proposed based on our pre-understanding of IA communication. A common coding scheme was then agreed on in a joint meeting. We formulated a communication model, Figure 3,based on the main categories from our code scheme consisting of communicating parties, communication context, content of the communication, and outcomes. The main categories included sub-categories and nodes. For example, the main category "Communication Party" included the sub-category "University" and the node "Researcher".

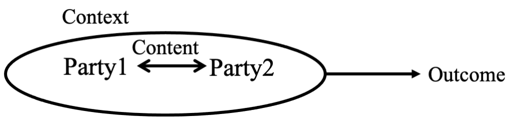

Figure 3: The communication model used as the basis for the coding of communication instances

In the next step, two researchers (1st and 2nd author) coded the material according to this scheme identifying all the communication instances according to the model. By a communication instance, we refer to a segment of text in the transcription that explicitly mentions communication between two communication parties. For each instance, we coded all the categories according to the model when possible. For example, the node "researcher" in the category "Communication Party" was used all times that in the transcription, one researcher communicated with someone else.

Analysis

In the following subsections, the results are presented with respect to the identified communication contexts. Curly brackets are used in the text to denote relations identified between factors facilitating communication, and subsequently promoted project outcomes. For example, "$\{F1 \xrightarrow{C} O1\}$" would mean that we have identified that the factor F1 facilitates IA communication and thereby promotes the project outcome O1. The letter C over the arrow indicates that it is an indirect relation over communication in the IA joint project. In some cases, more than one factor in combination were identified, and in some cases, more than one outcome were identified, which is marked by listing a set of factors/outcomes in parentheses.

IA Environment

The IA Environment refers to the whole research program as a context where communication occurred beyond the context of a specific project or research study. Some of the identified outcomes are not directly related to specific events or meetings. Rather, the participants expressed that the program in itself acted as *"an engine for generating more and more collaboration on all different levels"*.

The **long-term collaboration (F5)** supported by the 10-years research program facilitated communication between researchers and practitioners. Within the long-term horizon of the program, the participants' **social networks (O5)** were expanded $\{F5 \xrightarrow{C} O5\}$. The participants expressed that this long-term aspect of the context, in some cases longer than the research projects, was inductive to initiating **new studies (O6)**, including master thesis projects and research studies

$\{\text{F5} \xrightarrow{C} \text{O6}\}$. Similarly, the context provided junior researchers with an environment through which they had access to and could work with industry. The participants expressed that the continuous way of working and delivering value to the industrial partners motivated them to participate and thus led to **improve IA collaboration (O7)** $\{\text{F5} \xrightarrow{C} \text{O7}\}$. The industrial partners expressed that **the long-term collaboration (F5)** facilitated the communication and yielded benefits in the form of **new knowledge (O1)** that was useful both short-term and long-term, as expressed by one participant from industry $\{\text{F5} \xrightarrow{C} \text{O1}\}$: *"We could apply the results directly ... we got long term proof that enabled us to see that, yes, we are doing the right things"*. One participant also pointed out that the **long-term collaboration (F5)** facilitated staying focused on the agreed long-term plans without being affected by short-term industrial perspectives. Thus, the project was shielded from the industry's operational priorities. Overall, the long-term collaboration led to mutual learning about each other, whereby the IA communication was further facilitated.

The communication between industry and academic partners in the IA environment led to developing a **social network (O5)** where personal contacts, even beyond organisational affiliations, were established and kept active. During the project, some of these industry discussion partners became actively involved in the research as formal company contacts. Both researchers and practitioners expressed that the informal environment around the project was very positive and facilitated IA communication which generated additional joint work. Even further, the participants described that through participating in the project they strengthened their ability to communicate with industry and academia, and that this, in turn, promoted the identification of new ideas for further **new studies (O6)** and joint projects. In summary, communication in the social environment within the long-term research partnership stimulated knowledge exchange that promoted further and **improved IA collaboration (O7).**

Through our case study, we observed two outcomes that were promoted through the communication with industry on the academic side, one regarding teaching and one related to scientific forums. Several academic participants described that their involvement in the case project and communication with industry partners led to **changes in teaching (O8)**, in particular within the courses for which they are responsible. The awareness of industry needs and new knowledge gained through IA communication in the project thus promoted improvements to university courses. The communication between industry and academic partners around requirements and testing, created an awareness of the relevance and importance of this topic, which contributed to establishing a **new scientific venue (O9)** in the shape of a scientific workshop series on this topic. This new international forum provides researchers and practitioners with the opportunity to exchange knowledge and experience around one of the leading research topics of the case project.

Project-Related Meetings

Based on our empirical data, we have identified two main types of project-related meetings where industrial and academic partners communicated about research and industrial needs at a general (as opposed to meetings related to specific research studies, see next section). These two types of meetings were either of a creative nature or related to the project organisation. The creative meetings observed in our material took place during the formation phase when senior researchers met with industrial contacts. The communication at these meetings promoted **good IA collaboration (O7)** in jointly defining the research direction for the project. Through brainstorming sessions,h pa the main areas of interest were identified, which *"formed a frame for what was actually done"* in the project signalled one of the senior researchers involved in the management of the project. By **involving practitioners (F3)** also in this formation phase, and by basing the scope on industrial needs, thus ensuring **research relevance (F1)** further facilitated good IA communication in the project. There were multiple meetings with various companies during the formation phase. For some of these meetings, the relevance of the research and the involvement of practitioners facilitated good IA communication that led to initiating joint **M.Sc. projects (O6)** $\{(\text{F1, F3}) \xrightarrow{C} \text{O6}\}$, even for companies that did not become formal partners in the research project.

The most common type of project-related meetings were project meetings. For our case project, such meetings were held regularly every 6–8 weeks with all the involved researchers and the industrial contact persons. Most of the times participants were present in person at these meetings, with the exception of researchers from one of the university sites that occasionally attended via Skype. At these project meetings, status and intermediate research results were presented and discussed, and the industry partners shared new or changed needs from their perspective. The communication at these meetings played an essential role in promoting **good IA collaboration (O7)** in jointly detailing and agreeing to the research direction, and in initiating **new research studies (O6)**. The **frequency and style (F4)** of these meetings and the **active involvement of practitioners (F3)** created a good communication climate where ideas, needs and intermediate results were shared and discussed. For example, early on in the project, the industry contacts expressed a preference for focusing on decision-making specifically for testing when *"the companies said, we want to look at testing"*. This was agreed as the direction in which the research then proceeded, thereby strengthening the **relevance of the research (F1)** for the industrial partners. This relevance was further supported when *"the specific [industry] needs became studies"* and thus the IA communication led to jointly defining **new studies (O6)** $\{(\text{F1, F3, F4}) \xrightarrow{C} \text{O6}\}$. An example of this is a systematic literature study that was initiated when industrial partners expressed a need to understand the state of the art regarding test case selection and prioritisation [1]. Due to the industrial interest in this topic, one of the company contacts were actively involved in reviewing articles in this literature review and thereby acquired **new knowledge (O1)** $\{(\text{F1}, \text{F3}, \text{F4}) \xrightarrow{C} (\text{O1}, \text{O6})\}$ through participation in the research.

Studies

The research project included a combination of research studies and Master of Science (M.Sc.) projects related to the topics covered by the studied research project. The research studies were initiated based on joint agreement at the project meetings, see above, and were relevant to the industrial partners, thus ensuring research relevance for the joint studies. Similarly, the M.Sc. projects were highly relevant to industry since companies directly initiated them, sometimes with a researcher within the project and thereby facilitating IA communication in the shape of joint-supervision. These industrial M.Sc. projects applied scientific methods to design and validate solutions to industrially relevant problems for the companies.

Research Studies The research studies within our case project were performed with industry partners through **active practitioner involvement (F3)** in all phases of the studies, including research design, data collection and analysis. This active involvement, in combination with the **style of meetings (F4)** w.r.t. regularity and open discussions facilitated frequent and regular communication between the researchers and practitioners involved in each study. This factor was also observed facilitate communication at the project level meetings. Thus, the IA communication promoted that the company contacts gained **new knowledge (O1)** $\{(\text{F3}, \text{F4}) \xrightarrow{C} \text{O1}\}$ and deep insights into the research results through early access to results from the ongoing studies. This in turn enabled the practitioners to improve processes and tools within their companies and thus the IA communication also promoted **changes in practice (O3)** $\{(\text{F3}, \text{F4}) \xrightarrow{C} (\text{O1}, \text{O3})\}$. For example, two of the participating companies implemented changes to their test strategies based on results obtained and communicated within the project. One company representative expressed that *"when I saw some benefits, I implemented that"*, thus the fact that the research was **relevant (F1)** to the industrial partners facilitated the IA communication and led to **changes in practice (O3)** $\{\text{F1} \xrightarrow{C} \text{O3}\}$.

Most of the research studies within our case project were performed as case studies, and included activities at the companies such as *data collection* and *research seminars*. Some of the data collection methods that were used had the added benefit of disseminating **new knowledge (O1)** directly to the participating practitioners. In particular, this was the case for *focus groups* and *interactive posters* where the informants were presented with research ideas and topics and asked to reflect and give their views on these. This approach created a win-win situation, where active **practitioner involvement (F3)** in the data collection facilitated IA communication which then led to the practitioners gaining insights in the shape of **new knowledge (O1)** $\{\text{F3} \xrightarrow{C} \text{O1}\}$. For example, a set of focus groups were held around the topic of exploratory testing where different templates for expressing exploratory test cases were presented to the participants who then got to try them out [12]. These focus groups, and the IA communication that took place there lead to **changes in practice (O3)** for the participating test team who *"modified [their test practices] and have seen the direct impact"*. This team also spread their new knowledge to *"related teams within neighbouring areas"* within the company. Similarly, within a case study of ten teams, the team members were asked to assess the ease of working with other teams through voting using interactive posters. This approach of active **practitioner involvement (F3)** in the data collection facilitated IA communication and promoted an increased **awareness (O2)** {F3 $\xrightarrow{C}$ O2} of the research topic (communication gaps) and an interest in the ongoing research among company employees. This involvement also enabled the researchers to spread **new knowledge (O1)** {F3 $\xrightarrow{C}$ O1} of the underlying theoretical model to the entire studied department consisting of around 200 people. In this case, the company contact described that the use of interactive posters had promoted a new **awareness (O2)** and insight within the organisation regarding potential causes of communication gaps that help people to be more tolerant of each other and being proactive in how they communicate with "difficult" teams.

Research results were disseminated and communicated to industry in several ways, including *seminars* at the companies. The seminars led to the practitioners gaining **new knowledge (O1)** and increased **awareness (O2)** in general. As one researcher stated, *"some things are tacit, in the sense that you get more informed ... not necessarily a specific method, but you have awareness"*.

Industrial M.Sc. Projects The industrial M.Sc. projects provided a context where communication promoted establishing personal contacts and **social networks (O5)** between practitioners and researchers. For example, one of the company representatives in the research project first became acquainted with one of the researchers when they co-supervised an M.Sc. project at the company, and later started participating in other research projects. The practitioner's previous positive experience of working with the researcher positively influenced the **practitioner's attitude (F2)**, which further facilitated the practitioner's communication with researchers and **improved the IA collaboration (O7)** {F2 $\xrightarrow{C}$ O7}. Therefore, the practitioner was more **aware (O2)** {F2 $\xrightarrow{C}$ (O2, O7)} of ongoing research and available to participate in **new studies (O6)** {F2 $\xrightarrow{C}$ (O2, O6, O7)}. The **research relevance (F1)** and the **practitioner involvement (F3)** of the project played an important role regarding the scope and impact of the M.Sc. projects. Given that topics of the M.Sc. projects were of interest to the researchers who actively participated in the project, researchers and practitioners could define the scope of these M.Sc. projects jointly in order to become more relevant and useful to the companies and to the researchers. Furthermore, through communication of M.Sc. projects within the IA project, similar and overlapping interests were identified in other areas of the company, which led to broadening the outreach of the results from the M.Sc. projects.

Continuous communication between researchers and practitioners involved in relevant research provided a direct impact on practice within the participating companies. Industrial M.Sc. projects often provided direct value in the shape of **tools and source code (O4)** and facilitated the adoption of these results within the companies. For example, one M.Sc. project resulted in a tool for automatically prioritising issues in the company's issues management system. This tool was used as is in the company's software development organisation and thereby saved time and effort in issue prioritisation. Another example is an M.Sc. project that implemented an automatic checker for architectural rules that removes the need for manual reviews and thereby contributes to increasing the quality of the code. This tool was integrated into the company's development tool-chain and, thus enabled a **change in practice (O3)**. We see in our case study that the **research relevance (F1)** and high **practitioner involvement (F3)** developed a favourable environment that supported communication and contributed to concrete gains and values including industrially-relevant new **tools and source code (O4)** and **change in practice (O3)** $\{(\text{F1, F3}) \xrightarrow{C} (\text{O3, O4})\}$.

3.2 Results from survey

To validate the results from the case study, we conducted a survey with a broader sample of participants in our collaboration network. The results of the survey with respect to facilitators are shown in Table 4. For each facilitator, it is shown how many of the researchers and practitioners that have said that they agree it is an important facilitator of IA communication. The participants in the survey mentioned some additional facilitators. Researchers mentioned frequency of meetings, experience of the "other side", personal connections, and the attitude of the researcher (should be to transfer research, not collect empirical data). Information sharing, with frequency, and attitude were also mentioned by practitioners. They also mentioned the need for an understanding of the basic needs of both sides and more, actual relevance for both sides, and an understanding of the national innovation system. The results of the survey concerning outcomes are shown in Table 5.In the two columns marked 'Experience', it is shown how many of the researchers and practitioners that have marked that they have experienced the outcome. In the two columns marked 'Importance', it is shown how many of the researchers and practitioners that have marked that they think that the outcome is important to them.

For all three questions (confirm the validity of facilitator, experience of outcomes, and importance of outcomes), the respondents could mark any number of alternatives from 0 alternatives to all the given alternatives. However, all respondents marked a subset of the alternatives. We interpret this to mean that the respondents marked the alternatives that they thought were the most important to them. For example, our interpretation of a low number of participants answering

Table 2: Facilitators of IA communication, results from survey

Code	Name	Researchers	Practitioners
F1	Research Relevance	70%	62.9%
F2	Practitioner's Attitude towards Research	70%	65.7%
F3	Active Practitioner Involvement	70%	71.4%
F4	Frequency of Communication	50%	57.1%
F5	Long Term Collaboration	75%	57.1%

Table 3: Project outcomes supported by IA communication, results from survey

Code	Name	Experience		Importance	
		Researchers	Practitioners	Researchers	Practitioners
O1	New Knowledge	85%	94.3%	70%	88.6%
O2	Awareness	65%	88.6%	25%	68.6%
O3	Changes in Practice	75%	45.7%	40%	25.7%
O4	Tools and Source Code	55%	42.9%	15%	22.9%
O5	Social Networks	50%	77.1%	5%	48.6%
O6	New Studies	55%	42.9%	25%	20%
O7	Good IA Collaboration	80%	68.6%	50%	51.4%
O8	Changes in Teaching	40%	11.4%	10%	14.3%
O9	New Scientific Venue	30%	5.7%	15%	14.3%

that an outcome has been experienced does not necessarily mean that few participants actually have experienced it, but that they do not see this outcome as the most prominent or clearly noticed of the outcomes that they have experienced. For example, suppose a respondent has market four facilitators. In that case, the respondent may hesitate to mark a fifth facilitator, which would have marked if the four other facilitators would not have been marked.

Some additional outcomes were mentioned by the participants in the survey. From participants from academia, additional outcomes like knowledge of industry trends and real-world problems and industrial challenges were mentioned together with knowledge of vocabulary and terms used in industry. These could however be sorted into O2. From participants from industry, additional outcomes like access to international experience, improved company to company cooperation through research projects, and recruitment, e.g. through contacts with students were mentioned.

4 Discussion

We will now discuss the results regarding the facilitators (RQ1) and outcomes (RQ2) of communication within an IA joint project. For an overview, see Table 2 and Table 3.

4.1 Facilitators of IA Communication (RQ1)

Our study identifies a number of facilitators that contributed to good and productive communication in the case project. These facilitators can be viewed as characteristics of the context in which the communication occurs, of which some contribute positively to the outcome of the project. These facilitators are associated with the overall IA environment, to the practitioners involved, and to the style of meetings.

In the survey, all identified facilitators were seen as important by at least half of the respondents. As described in Section 4.2,we believe that facilitators that were not marked as important, are not unimportant but rather less important. Furthermore, we interpret the fact that many of the respondents believe that the facilitators are important means that the identified facilitators are valid also for a broader sample of IA collaborations beyond the studied case.

The relevance of the topic under study and the long-term horizon of the program facilitate IA communication within the project. The involvement of industry at the management level and participating in research favoured the relevance of the research. From our perspective, the project benefited from previous joint work, due to that the people involved had already established good practices for IA communication within the long-term program before initiating the studied project. This included the style and regularity of the meetings, ensuring research relevance and active practitioner involvement throughout each study. In the literature, the long term perspective is connected to a stronger level of commitment [10]. In our case, the long-term nature of the IA joint project provided the participants with the freedom to collaborate over a longer time. Within the long-term agreements, the participants had the flexibility to define studies without any additional formalities.

One major challenge when working with practitioners is the “lack or drop of interest/commitment” [10]. We identified active involvement and the attitude on the practitioner’s side as a key facilitator for good IA communication. We hypothesise that these two facilitators are due to two factors. Firstly, the relevance of the research performed motivates and stimulates practitioner involvement. Examples of this is the impact on practice observed in relation to the adoption of output from research and from M.Sc. projects. Secondly, the trust, respect, and mutual understanding of the existing project network facilitate communication between parties. In our case project, IA communication was natural and people knew whom to contact and how to work with their counterparts.

In this study, the frequency of communication was identified as one facilitating factor for IA communication. The frequency of communication was also identified as a facilitating factor for collaboration, for example by Rybnicek and Königsgruber [23]. Similarly, we found that active involvement from practitioners and their attitude towards research is critical to ensure the relevance of research results. These results are in line with the models proposed for joint research in software engineering [16, 18] that require a high degree of involvement from practitioners.

Finally, we identified the style of meetings as a facilitator of good IA communication, and associate this to the long-term nature of the project. Even if previous systematic reviews have not identified this specifically, Ankrah and Al-Tabbaa [2] "meetings and networking" is important for collaboration.

In the final project phase, the participants were familiar with each other and had an established way of working together. Each research study within the project shaped its own patterns and forms of communication; however, as new people joined the project and new studies were initiated the established ways of communicating were passed on or inherited. We observed a well-divided hierarchy of meetings, and the group involved in each study had internal and informal discussions. In each meeting, it was clear what type of concerns were addressed, e.g. on the topic, on the study, or on the whole project. This allowed for focused discussions of each concern at the relevant level. To some extent, it is possible to say that the facilitators that have been identified for communication correspond well to the facilitators identified in previous studies for collaboration in general.

4.2 Project Outcomes (RQ2)

We identify the project outcomes for both involved parties. For the academics, working with industry can impact teaching and research, and for practitioners, the impact can be seen in changes to practice. For both parties, the communication results in increased knowledge. Given that researchers are often teaching university courses, the knowledge exchange with industry has an indirect effect on the students and, therefore, on future software engineers. If the education of future practitioners receives the input from industry, this enriches a critical mass of (new) professionals and entrepreneurs who could then quickly become involved in the industry or launch new business ideas.

An important benefit for researchers is the access to and insights of the industry, enabling them to validate research and collect empirical data. Furthermore, the case project facilitated exchanges with researchers in general, both those directly involved in the project and others through personal contacts. These exchanges are valuable since they enable validating results and considering other viewpoints. Researchers, as well as practitioners, benefited from these exchanges.

For practitioner's, the outcomes of working with academia are both direct and indirect. Direct outcomes include changes in practice motivated by research findings, and tools and source code originating from the research that can be used at the companies. Industry often view these contributions as the main gain and outcome of the IA project, and they are also in line with the overall goals, especial goal ii, of the EASE program.

We have identified an additional indirect outcome of the IA communication in the shape of increased awareness of research among practitioners. Our analysis indicates that this awareness, in contrast to knowledge that has a direct industrial application, can impact the practitioner's work in several ways. This includes:

inspiration for new products, bench-marking with other practices, and increased confidence gained from selecting practices based on research findings. Overall, both types of benefits need to be considered when evaluating the industrial benefits of IA joint projects, since the potential gains influence industrial partners' willingness to commit and actively participate in IA joint projects. The possibility to reach these objectives, which are comparable to the objectives of the studied research project can be seen as an important factor for industry participants.

We identify knowledge exchange between industry and academy as an outcome of the communication that occurs within individual studies and throughout the entire project. As is expected, new knowledge is built-in research studies, and good communication contributes to achieving the goals of the studies. In addition, good IA joint projects contribute to a positive cycle that leads to further studies and mutual learning. Professional relationships are cultivated through project activities and exchanges during meetings. Many of these relationships go beyond the project lifetime and may lead to additional future IA interactions. In general, good IA communication fosters more collaboration.

In the survey, many of the outcomes received high scores, both regarding the degree to which they have been experienced, and to what extent participants think they are important. However, there are some outcomes that did not receive high scores with respect to all aspects. Outcomes related to industrial practice (O3 and O4) were considered less important than outcomes related to knowledge and awareness (O1, O2), indicating that there is a more general interest in outcomes related to knowledge as such than in immediate practical impact. Outcomes related to impact on research and teaching (O6, O8, O9) were, by a majority of the respondents, not marked as important, either by researchers or practitioners, indicating an expectation from both sides that knowledge transfer is unidirectional rather than bidirectional, which we believe may hinder good communication.

As described in Section 4.2 some additional outcomes were mentioned by the participants in the survey. However, very many of these are different expressions of the need for knowledge and awareness (O1, O2). Participants mention, for example, the need for knowledge about industrial trends and real-world problems. In the same way, participants mention, for example, access to international experience. However, participants from practice also mention outcomes, which are outside the scope of IA communication, like company to company cooperation and recruitment of personnel.

4.3 Validity of Contribution

Our main contribution is the identification of facilitators of communication in an IA joint project and related outcomes. We assess this contribution by discussing threats to validity and steps taken to mitigate these.

Construct Validity Our empirical data was collected from a retrospective meeting with the goal to reflect on the IA collaboration based on a timeline visualising projects events and outcomes. The objective of that meeting was to investigate how industry and academia had worked together within the research program, not specifically focusing on communication in isolation. There is a risk that the retrospective did not focus enough on communication for this study. However, a large share of the timeline data was focused on communication, which is also one reason why we study mainly communication in this study. We found that the data was useful to study communication due to the variety of communication instances found in the material, and the survey part of this research helped us to mitigate this risk by confirming the results with project participants and survey respondents.

Internal Validity relates to the suggested relationships between data entities, in this case, facilitators and outcomes. Propositions of these relationships are based on an aggregation of assumed connections between the entities in our coding scheme. These connections were identified in the data, and need to be further tested. There is a risk of researcher bias in the analysis which may affect the reliability of our results. We partly mitigated this risk by working in pairs on systematically applying thematic coding. Our familiarity with the project is a risk and a strength. The risk is the one of confirming our prior beliefs. This risk is mitigated partly by using a bottom-up approach to the coding (i.e. the facilitators were derived after the coding), and partly by asking other project members to read and comment on the results. This validation was performed by sending the manuscript to three practitioners and two senior researchers involved in the project, four of which responded. Furthermore, the risk of misinterpretations is partly mitigated by the researchers being familiar with the project, and knowing the people involved.

External Validity describes the generality of our results. In this case, we formulate our contribution to be applicable in any IA joint project, and it can, thus, be tested also in other contexts. Our results are derived from observations in a single case study. An initial step towards external validity was the survey where additional people from industry and academia confirmed the identified facilitators and outcomes. Survey participants mentioned additional factors, e.g. mutual trust and understanding, style of communication, researcher's attitude, and recruitment of graduating students. However, the main result of the survey with respect to external validity, as described in Section 4.2, is that the generality is strengthened through the survey. Further research may investigate these factors and strengthen the generality of our results in further surveys.

5 Conclusions

Communication plays a crucial role in any collaboration, so also in research projects, both in facilitating the project as such and in creating a shared understanding of the goals and outcomes of the project. In this study, we have analysed the communication within a 3-year research project, which in turn was part of a 10-year research program. The overall goals of the program were, from the industry side, to increase the competence of personnel, and, from the research side, to perform research of high scientific quality that is useful to industry. Thus knowledge sharing and knowledge co-creation were expected outcomes of bringing the researchers and practitioners together in various projects, both of which rely on good communication between the parties.

We collected empirical data that was analysed according to a simplified model of communication (Figure 3) describing instances of communication where each instance represents IA communication between two parties, within a context and having explicit communication outcomes. Through analysis of such communication instances, we identified elements that facilitate communication between industry and academic partners and examples of project outcomes that were promoted by good communication. These facilitators and outcomes, as reported in Section 4, provide empirically-based insights that may be used to guide the setup of similar joint projects and improve IA communication. Furthermore, the extended model of IA communication including the observed contexts of communication, facilitators and project outcomes may inspire future research on the characteristics and relationships between these proposed constructs of IA communication, which we find much needed.

In summary, the following recommendations may facilitate IA communication in joint research projects and subsequently contribute to achieving the project outcomes:

Ensure that research is relevant to all participants by discussing and jointly agreeing to the scope of joint research programs, projects and studies. When the research topics and results are relevant to the practitioners and applicable to their experienced work challenges, they will be more willing to engage in research activities. We noticed how addressing problems experienced by practitioners contributed to developing a favourable IA collaboration climate supported by communication that led to changes in practice and new knowledge.

Foster positive attitudes towards research by listening to each other's needs and interests, and aiming to provide value to practitioners. The view and attitude of practitioners towards research, researchers and research results influence their involvement in and commitment to research activities. We noticed that practitioners with trust in and previous positive experiences of collaborating with researchers had a positive attitude towards further such collaboration, which facilitated the communication with researchers.

Promote active practitioner involvement by openly discussing plans and emerging research results, and by inviting practitioners to take an active role, e.g. in reviewing papers, writing articles. An active engagement of practitioners in research projects contributes to identifying and addressing industry-relevant problems in the research studies. Furthermore, these engaged practitioners are critical in leading and promoting changes in practice based on research results. We noticed that the active involvement of practitioners was a critical factor that led to having discussions around industry-relevant topics with researchers. From these dialogues, new studies emerged around industry challenges, and practitioners were aware of research in the field.

Hold both formal and informal meetings with a clear focus and adapted to the specific needs, e.g. of overall project synchronisation versus work meeting. IA communication and goal achievement are supported by a good balance of formal meetings for project management and open and informal meetings where creativity flourishes.

Establish a long-term collaboration between industry and academia through joint projects and networking events. A Long-term collaboration contributes to creating social networks, identifying more research studies, and the possibility to apply results in the academic and industrial contexts. In addition, the long-term aspect of the collaboration allowed researchers and practitioners to gain insight into each other's spheres and to develop good practices and ways of working together.

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CHAPTER III

GUIDELINES FOR CONDUCTING INTERACTIVE RAPID REVIEWS IN SOFTWARE ENGINEERING – FROM A FOCUS ON TECHNOLOGY TRANSFER TO KNOWLEDGE EXCHANGE

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Abstract

Evidence-based software engineering (EBSE) aims to improve research utilization in practice. It relies on systematic methods (like systematic literature reviews, systematic mapping studies, and rapid reviews) to identify, appraise, and synthesize existing research findings to answer questions of interest. However, the lack of practitioners' involvement in the design, execution, and reporting of these methods indicates a lack of appreciation for knowledge exchange between researchers and practitioners. Within EBSE, the main reason for conducting these systematic studies is to answer the practitioner's questions and impact practice. However, in many cases, academics have undertaken these studies without any direct involvement of practitioners. This report focuses on the rapid review guidelines and presents practical advice on conducting these with practitioner involvement to facilitate knowledge co-creation. Based on a literature review of rapid reviews and stakeholders engagement in medicine and our experience of using secondary studies in software engineering, we propose extensions to an existing proposal for rapid reviews in software engineering to increase researchers-practitioners knowledge exchange. We refer to the extended method as an interactive rapid review. An interactive rapid review is a streamlined approach to conduct agile literature reviews in close collaboration between researchers and practitioners in software engineering. This report describes the process and discusses possible usage scenarios and some reflections from the proposal's ongoing evaluation. The proposed guidelines will potentially boost knowledge co-creation through active researcher-practitioner interaction by streamlining practitioners' involvement and recognizing the need for an agile process.

1 Introduction

Software engineering research aims to establish software development practice on scientific foundations. This ambition requires that research is relevant and accessible for practice. Evidence-based software engineering (EBSE) is one such initiative to provide the best available evidence to support software development and maintenance. Often, a single empirical study provides insufficient confidence in the strength of evidence. There is a need to synthesize available research (where individual studies often have contradictory results) on a topic of interest. The EBSE) [31] approach has the following five steps: (1) convert a practical information need to an answerable question, (2) identify available evidence to help answer the question, (3) critically appraise the evidence, (4) make evidence-informed decisions, and (5) evaluate the effectiveness and efficiency of steps 1-4.

The EBSE community has developed several systematic secondary study methods for steps 2-3, including systematic literature reviews (SLRs) [32], systematic mapping studies (SMS) [43], and rapid reviews (RRs) [11]. Similarly, several authors have proposed solutions to facilitate step 4 in the EBSE process by introducing knowledge translation [7] or the technology transfer models [38].

Among the secondary study methods, mainly RR and SLRs are intended to support changes in practice. The SMSs only develop an overview of existing research on a topic. They are not intended to provide actionable insights for practice. SLRs risk being less attractive for practitioners because of the time frame needed to complete them. The time limitation of SLRs is overcome with the use of RRs. RRs are a variant of SLRs that simplify several steps of SLRs to provide information under time restrictions.

However, secondary studies are often conducted without any participation of practitioners. This lack of involvement can be partly explained by the implied objectivist view of knowledge [26] in the five-step EBSE process. In steps 2-3, knowledge is treated as objective, disembodied from the context, and codified, which in step 4 is transferred or communicated to practice. We overcome this limitation by extending the guidelines for RRs guided by the following principles: 1) *Prioritize exchange* between researchers and practitioners. 2) The review is conducted to be *relevant for practitioners* according to their context. 3) A *close collaboration* is expected while doing the review.

This report presents an extension to the existing guidelines for designing and conducting RRs in SE [11]. It includes an emphasis on iterative and flexible design and ways to increase practitioner involvement in RRs, we refer to this extended version as interactive rapid review (IRR).

Like agile software development, IRR aims to bring the stakeholders (practitioners and researchers) of the product (in this case, literature syntheses) closer together with shorter lead times, increased communication, and flexibility in the process. The iterative and flexible design recognizes that the information need will be refined and may change during an IRR. Similarly, the interaction is critical to developing a deeper understanding of the context where practical information need is situated and to improve the relevance of the results.

The extension is based on a literature review from evidence-based medicine (EBM) where rapid reviews are extensively used [28,30,39,50]. We further supplement these with our own experience of having conducted several SLRs targeting industrial needs (e.g., [1, 3, 15, 16]) and several industry-academia collaboration projects.

We envision that conducting an IRR based on the proposed guidelines may foster knowledge co-creation, bringing several benefits. The IRR results tailored for the practitioners' needs, improve research utilization in practice. Besides, conducting the IRR favors mutual understanding between practitioners and academics that paves the way for further collaboration.

The remainder of the report is structured as follows: we describe the related work and our approach for developing the IRR guidelines in Section 2. In Section 3, we describe the complete proposed guidelines for interactive rapid reviews. We further discuss the use and implication of IRRs in Section 4 and conclude the report in Section 5.

2 Background

2.1 Secondary studies in software engineering

Researchers in software engineering have widely adopted the use of secondary studies as a means to synthesize software engineering knowledge [5]. A large number of SLRs and SMS have been published in software engineering. Also the process itself, to conduct these secondary studies, has been a research topic, and some researchers have proposed improvements to the methods and new strategies. Some examples are snowballing as a search strategy [57], reporting guidelines for search [4], study selection procedures [2,42], use of machine learning for automation of search and selection [46], and studies about when to update SLRs [37].

Recently, Felizardo et al. [19] published a systematic mapping study and a survey on the value of using secondary studies in software engineering. They observed that secondary studies mainly have been used in academic environments, for teaching purposes and to identify gaps in research. The value of conducting the studies is described in terms of ability to develop research skills in students and junior researchers and to provide insights to plan future research. Little is mentioned about the interaction with practitioners while conducting the studies or about the impact of secondary studies in industry.

Some voices in the software engineering research community have claimed that secondary studies need to connect more with practice. Budgen et al. [6] suggested aspects to improve when reporting systematic reviews to make the results more meaningful for teachers and practitioners. Le Goues et al. [34] reflected on the advantage to connect research evidence with recommendations for practitioners.

2.2 Rapid reviews in software engineering

Rapid reviews were introduced in software engineering by Cartaxo et al. with the primary goal to transfer knowledge from academia to industry [8–10]. Like previously introduced EBSE methods the rapid review term originates from evidence-based medicine. Cartaxo et al. [11] describe rapid reviews as secondary studies that aim to "provide evidence to support decision-making towards the solution, or at least attenuation, of issues practitioners face in practice". The reviews may be seen as a variation of systematic literature reviews where some steps are omitted or simplified to reduce completion time. In medicine, there are variations of the method to conduct a rapid review, however, the approaches share the following common aspects:

- The review is conducted in collaboration with practitioners and refers to practical problems in their context.
- The review is conducted in a short time and at a low cost.
- The review's results are "reported through mediums appealing to practitioners."

Rapid reviews should not be misunderstood as ad-hoc literature reviews or lax reviews. Instead, rapid reviews are a systematic approach with a transparently documented process. Cartaxo et al. propose rapid reviews in software engineering to be lightweight secondary studies to deliver evidence to practitioners in a short time to support decision making [11].

Rapid Reviews have two characteristics that make them a good candidate for connecting research and practice. First, they are conducted in a short period of time, which is probably appreciated by practitioners. Second, the studies are framed in the context of practitioners making the results relevant for them. This report elaborates on the researcher-practitioner interaction in such studies and describes the procedure for conducting interactive rapid reviews (IRRs).

2.3 Stakeholder engagement in secondary studies

In EBM, rapid reviews are used to support policy decision [30,40,41,53], support decision-making under tight schedule restrictions [25,44,49,52,53] and to a lesser extent to identify areas for further research [39]. Deverka et al. [14] investigated the engagement of stakeholders in secondary studies, and concluded that stakeholder engagement contributes to developing a shared understanding of the knowledge and increasing the outcomes' relevance. In their study stakeholder refers to any person or organization with a direct interest in the secondary studies' process or outcomes and stakeholder engagement as "an iterative process of actively soliciting the knowledge, experience, judgment, and values of individuals selected to represent a broad range of direct interests in a particular issue". In 2017, the world health organization (WHO) published a guide about rapid reviews to strengthen health policy [51]. The guide was compiled by researchers and provide practical advice regarding various aspects of rapid reviews. Among other things, the guide addresses how to engage policymakers and health system managers in conducting rapid reviews.

3 Interactive Rapid Reviews

In this section we describe the preliminary steps for conducting an IRR and propose ways for researchers and practitioners to interact throughout the process. We base the proposal on a literature review of the use of rapid reviews in EBM, including 48 meta-studies and reflections on the method. The presented procedure is aligned with the one proposed by Cartaxo et al. [11] and reflects our own experiences of conducting interactive literature reviews [1]. Fig. 1 shows the activity flow to conduct the review.

Our proposal for IRR consists of five steps that are described in more detail later in this Section. The first step is to prepare the IRR and identify information needs based on a practical problem. In the second step, the research questions are identified, and an initial version of the IRR protocol is developed. The protocol keeps track of decisions and activities throughout the IRR. The third step consists of searching and selecting papers to find a limited set of papers to answer the research questions. Decisions about terminology and relevance are validated with practitioners. Based on the selected set of papers, the IRR report and dissemination documents are co-designed and developed during the fourth step. Finally, in the fifth step, the results are disseminated among the practitioners. Notice in Fig. 1.

that the steps are conducted interactively with practitioners and that the general flow is iterative, where according to the feedback, the step outcomes are refined.

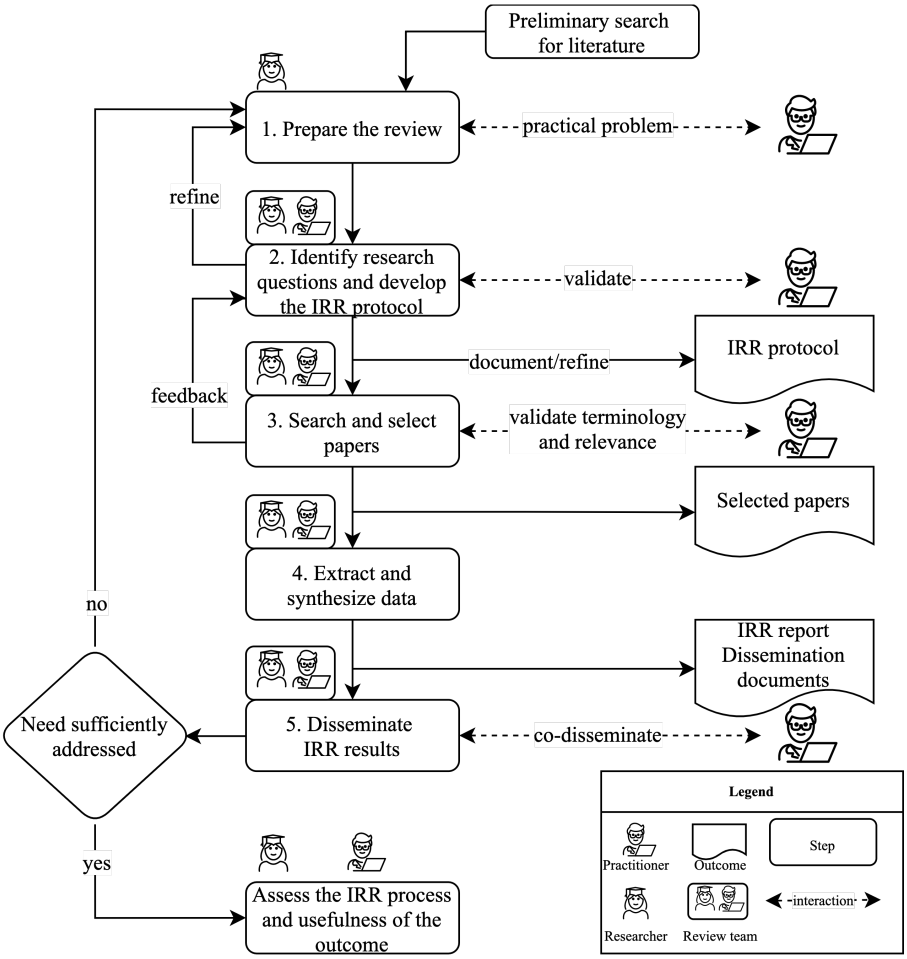

Figure 1: Workflow for performing an IRR

Table. 2. shows the central steps of an IRR in the first column (these have been adapted from Cartaxo et al. [11]). The second column highlights the contribution of our proposal with activities suggested to promote interaction with practitioners, and the third column lists the outcomes for each step. In the rest of this section we discuss each of these steps and possible interaction in more detail. Note that, when conducting an IRR the following general aspects should be considered:

- An IRR can be conducted in many scenarios throughout the researcher-practitioner relationship. The main goal of this type of review is not to publish a research paper, but to align communication between stakeholders and gain relevant knowledge to solve a practical problem.

- An IRR is preferably lead by researchers as they have more experience dealing with the scientific literature. Practitioners provide insights to keep the IRR relevant for practice with a consideration of their context.

- Conducting an IRR is an agile process. Similar to agile software development, our proposal for IRR embraces the following principles: smooth communication between researchers and practitioners; meaningful results in context; joint work with practitioners; and response to change and flexibility.

3.1 Prepare the review

Fig. 2. shows the activities to prepare the review. In this step, the review team is formed, and information need is identified and described in context. The interaction between researchers and practitioners aims to get a commitment to performing the IRR and identifying a context-relevant problem for the IRR.

Researchers lead the process to conduct the IRR. First, they form an initial review team based on the broad SE knowledge area (like software testing or requirements engineering) and the practitioners' interests. Ideally, the review team should comprise at least two researchers, but it may be formed only by one researcher. Having at least two researches enriches the discussion and helps to improve the reliability of the study. It is even better if one of the researchers has experience conducting a systematic secondary study like SLR, SMS, or RR. During the review, the review team performs the search, selects papers, extracts, and synthesizes knowledge. Practitioners may or may not directly participate in these tasks depending on their degree of involvement. However, throughout the IRR, they are expected to, at the very least, have communication channels open with the review team to answer questions and provide feedback related to the relevance and context. Before starting with the review, researchers and practitioners need to clarify mutual expectations, agree non-disclosure agreements if applicable, and define roles and responsibilities [29].

In an initial presentation meeting, researchers introduce an overview of the IRR method, outcomes, roles, and responsibilities. This presentation helps to develop a shared understanding of expected outcomes and commitment. Before, the meeting, researchers do a preliminary search to get a sense of the literature in the field and support the dialogue with practitioners. Secondary studies are especially useful for this purpose [30, 36].

Step	Activity to promote interaction	Outcomes
1. Prepare the review	1.1. Form an initial review team of researchers and practitioners. 1.2. Present IRRs (typical aims, process, expected outcomes, timeline and commitment). 1.3. Collaboratively, identify and rank a list of information needs appropriate for an IRR. 1.4. Choose a prioritized information need of mutual interest. 1.5. Agree on practitioners' involvement and update the review team. 1.6. Input meeting: to present current practices and context.	Review team Description of information need Review topic
2. Identify research questions and develop the IRR protocol	2.1. Jointly, define the research questions. 2.2. Prepare and validate with practitioners the search strategy and inclusion/exclusion criteria.	IRR Protocol
3. Search and select papers	3.1. Perform the search. Present and validate the search results. 3.2. Apply inclusion/exclusion criteria 3.3. Update / extend the search	Papers to analyze
4. Extract and synthesize data	4.1. Co-design IRR reports and dissemination documents 4.2. Extract information and elaborate reports 4.3 Reaction meeting: present the initial results to the practitioners involved	Reports and dissemination documents
5. Disseminate IRR results	5.1. Identify the audience and medium of communication 5.2. Disseminate results to practitioners 5.3. Practitioners disseminate to other practitioners 5.4. Disseminate results to academic audiences	Reports and dissemination documents

Table 2: A list of activities proposed to increase the involvement of practitioners in rapid reviews (the steps in the first column are adapted from Cartaxo et al. [11]

When practitioners have proposed the IRR topic concerning a practical problem, researchers and practitioners continue to identify context elements and re-

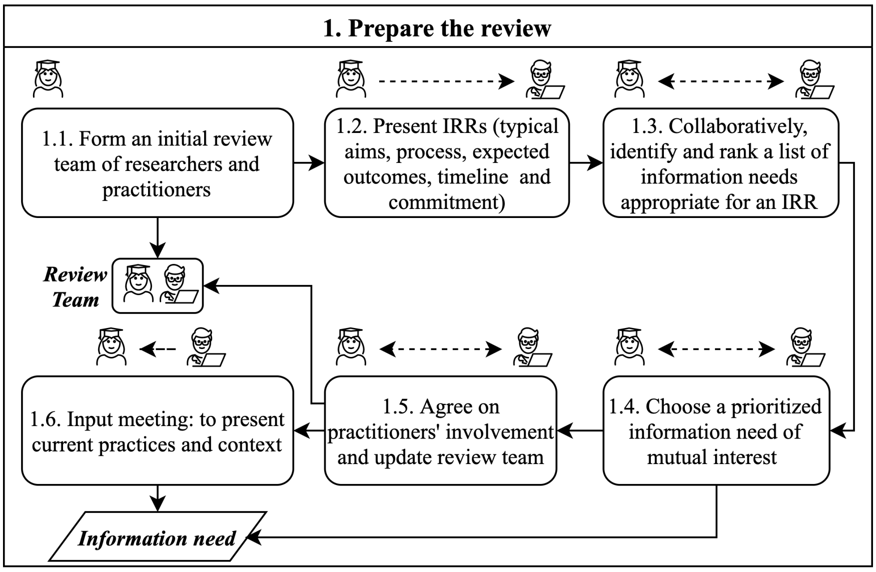

Figure 2: Prepare the review aims at get a shared understanding of what is an IRR, the expected outcomes, and to plan the work ahead

search questions. Although, they have identified a practical problem they may need to specify the IRR scope further. To narrow the review topic, researchers may propose a shortlist of topics to the practitioners based on the results of the preliminary search and the practical problem [14]. With the list of topics, the practitioners rank the suggested topics according to their problem in context or suggest other directions. This exchange helps to agree on the IRR topic and contributes to making it interesting for both researchers and practitioners.

After the meeting, the review team may be updated with practitioners or new researchers. According to the practitioners' interest and familiarity with scientific literature, their participation may vary from being part of the review team to only provide feedback at specific points, e.g., clarifying terminology or the relevance of specific studies. The review team defines practical aspects like communication channels, file sharing, meetings calendar, and estimate the practitioners' time required to conduct the review, including both meetings and time required to answer questions.

Researchers need to get a good understanding of the practical problem and context variables. Researchers and practitioners may have an input meeting. During the input meeting, practitioners present the current practices in their context [14]. This meeting allows the review team to get a first approach to the research questions and keywords when preparing search queries.

At the end of this step, a team for the review has been formed. The team has an initial view of the problem in the context of practitioners. The review team has a preliminary sense of research in the field and defined some practicalities like communication channels, meetings calendar, and follow-up meetings.

3.2 Develop the IRR protocol

For this step, we suggest two activities (see Fig. 2) related to define research questions with practitioners and prepare and validate the search strategy and inclusion/exclusion criteria.

The IRR protocol keeps track of the decisions and steps to conduct the review [21, 23]. During this step, the review team develops the protocol. However, this step may be revisited and the protocol updated in several iterations as new insights about both the context and the literature are gained [24, 35]. This favors the rigor of the study and the trust in the results. The protocol should contain at least [24]:

- Problem definition
- Research questions
- Search strategy
- Exclusion criteria
- Synthesis methods
- Initial proposals on how to disseminate the results

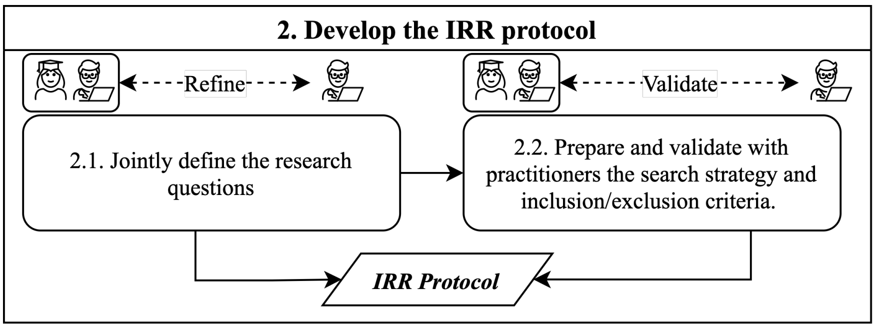

Figure 3: IRR follows a protocol that keeps track of decisions during the method

Research questions are crucial in the review because the search and knowledge synthesis is based on them. Practical questions are more suitable for this type of review, instead of general and broad questions [20]. Compared with SLRs, the research question's scope is narrower as the questions in IRR address practical questions in a specific industry context [17, 53].

Researchers are used to working with research questions; thus, they may guide the formulation. They frame preliminary questions based on available literature and the practical problem. When defining research questions for IRR, it is essential to ensure alignment with practitioners' terminology. Questions are refined based on the exchange between the review team and practitioners to ensure that the final questions are relevant and include the particular practitioners' context [24,36]. After a preliminary search, the review teams should evaluate if the research questions are suitable for an IRR according to the existent primary studies. If a preliminary search does not find related studies, it is probably unsuitable to continue with this approach.

The IRR protocol includes the search strategy and the inclusion/exclusion criteria. To define the search strategy, the review teams may consider insights from the preliminary search, the terminology extracted from the interaction with practitioners, and the identified context elements.

In an IRR, the review team uses shortcuts to reduce the number of sources to analyze and find more specific papers. Some of the shortcuts include [17, 20, 27, 33, 36, 50]:

- Base the review only in secondary studies
- Use only one search engine e.g., Scopus, Google Scholar
- Limit to only studies published in English
- Limit to specific journals and conferences
- Limit from some specific date range
- Limit according to the methodology of the study e.g., case studies.

If the review team may consult researchers with experience in the IRR topic, they can conduct peer review on the search queries to verify that all related terms are included [36, 47]. Some other search strategies like snowballing [20] or including grey literature may be considered if the review team has experience with these techniques. Regarding the inclusion/exclusion criteria, fixing strict exclusion criteria reduces the number of papers and thus favors rapidness [50].

This step should result in a preliminary version of the IRR protocol containing research questions, and a preliminary version of the search strategy, and inclusion/exclusion criteria. In addition, the review team may have initial ideas about how results will be communicated and the type of reports and documents to develop.

3.3 Search and select papers

Through the activities in this step (see Fig. 4), the review team performs the search and selection of papers. These activities require high interaction with practitioners to validate specific aspects such as terminology, the relevance of specific studies, and context elements. The review team may decide to update or extend the search of sources by conducting snowballing or manual search [20]. These decisions need to be updated in the IRR protocol.

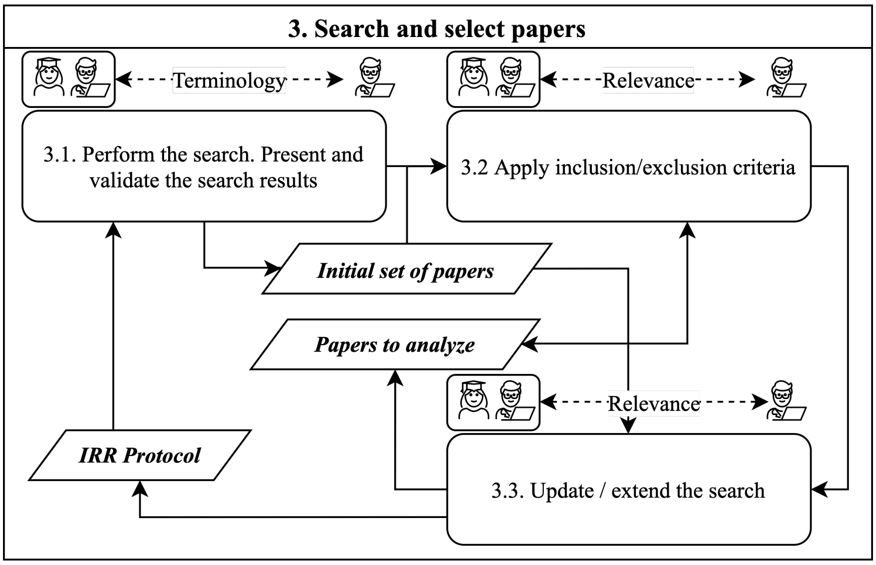

Figure 4: The search and selection of papers is a critical step to ensure the rapidness and relevance of the IRR

With the search results, the review team applies the exclusion criteria to select the set of papers included in the review. As in SLRs, the papers' selection may be divided into the following activities: Review the titles, read the title and full abstract, and read the full paper. A common practice in medicine is that only one team member make decisions about inclusion/exclusion of studies. Leaving the responsibility to only one reviewer reduces the time and avoids solving discrepancies about including/excluding specific studies [17, 23, 30, 50].

During this step, the review team may use tools to support the selection of papers. Felizardo and Carver [18] conducted a systematic search for approaches and tools to automate the SLR process. They found that selection of studies is the activity with most tool support. In their study, the authors analyze the different approaches and provide references to tools. At this point, the review team has a set of papers to analyze to answer the research questions.

3.4 Extract and synthesize data

The activities in this step, see Fig.5, aim to prepare and develop the material that will be used to disseminate the IRR results.

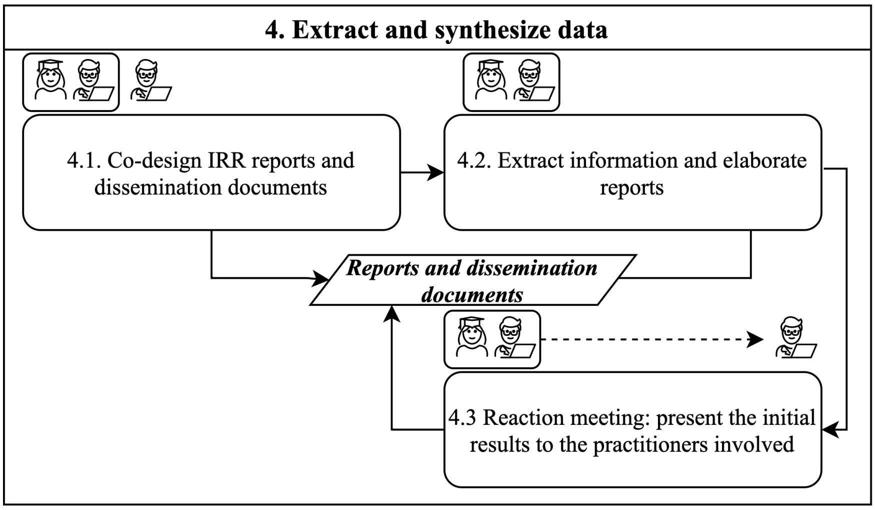

Figure 5: During this task, the review team extracts and synthesizes information from the selected paper to answer the research questions.

Before extracting information from research papers, the review team designs initial reports that will be shared with practitioners. This allows the reviewers to focus on what to search for in the papers. We suggest presenting the result as narrative summaries. A narrative summary is a text that summarizes the findings of the synthesis. More advanced methods like thematic analysis [13] may be used only when having a large number of primary studies, and the process will not impact the time to completion. The synthesis is mainly oriented to describe research results through a narrative summary [22, 45].

In a reaction meeting [14], the review team presents the IRR results to the initial group of practitioners. The practitioners provide feedback and suggestions on how to communicate them to a larger audience. Keep in mind that software engineers, with few exceptions, do not read scientific papers. Thus, the reports need to be designed in a practitioner friendly manner [30]. Some alternatives are visual abstracts [48], evidence briefings [12], presentations, seminars, and posters.

3.5 Disseminate IRR results

Fig. 6. shows the suggested activities in this step to disseminate the IRR results.

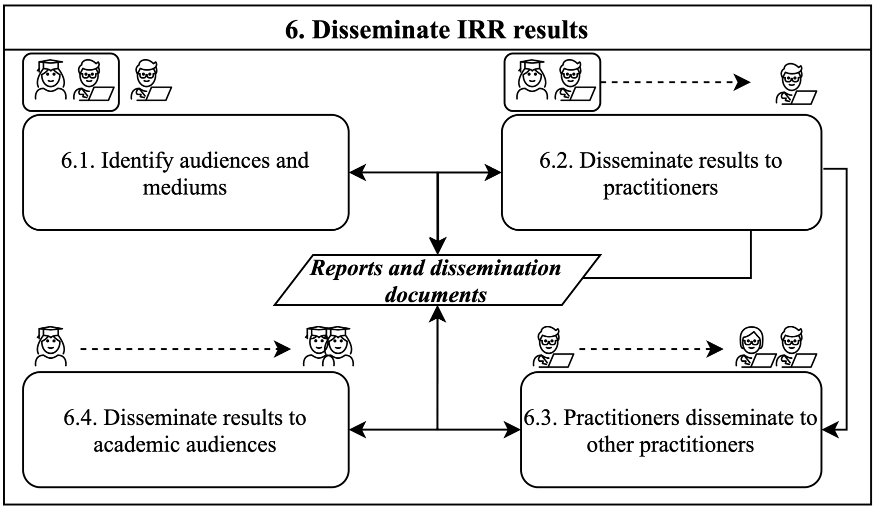

Figure 6: The last step in conducting the review is to disseminate the results.

Initially, the results are communicated to the practitioners involved in the review. Later, the results may be shared with other practitioners in the same organization. For some groups, the diffusion may require to adapt or create new ways to share the results. For example, one group may need less scientific details, while others may require only to present tools or source code. These strategies and diffusion actions need to be coordinated with practitioners who know their context and colleagues better.

Although an IRR's main goal is not to produce a scientific publication, some results may be relevant for academic audiences [33, 39]. If it is the case, the researcher may find the appropriate medium and publish the results. Otherwise, and following non-disclosure agreements, the results may be shared via social networks or in other academic spaces such as workshops, university courses, and online discussion.

3.6 IRR evaluation

Once the IRR results have been disseminated, the review team and the practitioners evaluate if the IRR results support the initial information needs. A possible result is that researchers and practitioners want to explore further a specific topic or take another perspective. Thus, they identify new research questions and apply the steps again. Another possible result may be the identification of a gap in research. If it is the case, the results are a starting point to design and support new research.

In our view, conducting an IRR is an opportunity for mutual understanding between research and practice. When evaluating the IRR, consider besides the outcomes the learnings by participating in the review. By getting involved in the IRR, practitioners develop an awareness of research results and their application in practice while researchers better understand industry challenges and their context.

4 Discussion

RR emerged in medicine as a faster approach than systematic reviews to synthesize knowledge from primary studies. While systematic reviews are well-defined, rapid reviews is an umbrella term that includes a spectrum of related methods. An important aspect of the approach presented in this work is the knowledge exchange between researchers and practitioners. In medicine, there are review groups that work on synthesizing knowledge for decision-making by following standardized protocols accepted by the community. In software engineering, knowledge synthesis is done by the knowledge-users themselves, either researchers or engineers, with different approaches and varying degrees of rigor.

In medicine, practitioners rely on and expect input from academia, while in software engineering, new ideas may be more important than evidence for practitioners approaching academia [55]. Proposed interventions need to be adapted to and re-evaluated in the new context [54]. This can be seen as an argument for allowing synthesizing knowledge in an earlier stage. However, to enable the validity assessment of the conclusions drawn, transparency and context-dependency is key.

RR lack a unique method, but there are some similarities to traditional systematic reviews. Even if the RR approaches are expeditious, they follow a structural set of steps where the research questions are defined at the beginning of the review, making it possible to track the review process and, if necessary, repeat it. Transparency is important since the processes and decision making are faster than in systematic reviews. For these reasons, all the decisions are documented and reported.

Interactive Rapid reviews are conducted in less time than systematic reviews since there is a requirement to have shorter feedback cycles when working with practitioners who want to receive knowledge to affect their products, processes, etc. One way of shortening the time in an IRR is to keep a narrow scope. Here a balance must be decided between answering all relevant questions for a subject and answering only the questions of interest in the collaboration between the practitioners and the researcher. Compared to a traditional review, the selection of subject scope is probably more dependent on practitioners' interests. To what extent this means that relevant and important areas in the literature is not prioritized can be a question for further research.

Another way to decrease the time of IRR is to use shortcuts to expedite the process. To satisfy the time restrictions, rapid reviews skip steps carried out in traditional systematic reviews or limit some steps. Some examples are: avoiding analysis of inter reviewer agreement, not conducting quantitative analysis, and limiting the search, e.g. by language, time, or the number of databases. Here, a balance must be decided between traditional rigor and obtaining information in a timely way.

Rapid reviews have the potential to bring researchers closer to practitioners and improve communication between them. IRRs aim to maintain professionals' interest and commitment during the review and provide them with useful results. For researchers, we see in IRR an opportunity to get closer to the industry, gather data and information, which we believe is essential in software engineering research.

We consider, like Wohlin [56], that working with industry is more about knowledge exchange than about knowledge transfer. Consequently, our proposal for IRRs is base on the idea that conducting a rapid review with practitioners is an opportunity to establish a bidirectional dialogue where researchers and practitioners get the chance to learn from each other. This interaction facilitates mutual understanding, favors research relevance, and paves the way for future collaborations.

5 Conclusion and Future Work

Our proposal for IRR reinforces the interaction between researchers and practitioners while performing the review. We believe such researcher-led, interactive reviews may improve the knowledge exchange between researchers and software engineering professionals. An IRR starts from a specific knowledge need from practitioners, which implies that the topic is relevant for practitioners from the beginning. During the review, practitioners are highly involved in refining the research questions and defining the protocol, which increases the researchers' understanding of the specific context. Throughout the selection of studies and information extraction, researchers and practitioners keep communicating, contributing to learning from each other. IIR results are disseminated in a practitioner friendly way, making them easier to use.

According to the points mentioned above, we included in our proposal opportunities to focus on the researcher-practitioner exchange during the review. Overall, we recognize in conducting rapid reviews an opportunity to establish a bi-directional exchange between researchers and practitioners that enables future joint work.

Finally, we identified the some potential benefits and challenges of conducting rapid reviews in software engineering. We envision that conducting rapid reviews in collaboration with practitioners may: 1) incentivize a dialogue between researchers and practitioners, 2) provide research results to the industry that are relevant for their context, 3) provide researchers opportunities to learn about the practitioner's problems and their context, and 4) develop networks that could be the base for new collaborative projects.

Similarly, we find the following points as challenging while conducting a rapid review. 1) Time constraints can influence the quality of the review. 2) There is a lack of clear guidance on how to perform rapid reviews and tools to verify the review's quality. 3) There could be misunderstandings about the depth and breadth of a rapid review. 4) There may be a lack of research results on the topic selected. 5) Practitioners' involvement may lead to bias due to practitioners' oriented results.

To address these challenges, we suggest to: 1) keep a protocol that contain all the decisions made in the review to evaluate the strength of conclusions, 2) follow the guidelines proposed in this paper, 3) reinforce transparency as an essential practice when working with industry, and 4) conduct a preliminary search and refine the research questions to identify when there is no available literature in the area, and 5) declare expectations from the beginning about the goals and role of researchers.

As future work, we plan to validate this proposal empirically by studying actual cases of rapid reviews with the industry and evaluate how rapid reviews impact researcher-practitioner communication within and beyond a research collaboration.

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