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Challenges and best practices in industry-academia collaborations in software engineering: A systematic literature review

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ABSTRACT

Context: The global software industry and the software engineering (SE) academia are two large communities. However, unfortunately, the level of joint industry-academia collaborations in SE is still relatively very low, compared to the amount of activity in each of the two communities. It seems that the two 'camps' show only limited interest/motivation to collaborate with one other. Many researchers and practitioners have written about the challenges, success patterns (what to do, i.e., how to collaborate) and anti-patterns (what not do do) for industry-academia collaborations.

Objective: To identify (a) the challenges to avoid risks to the collaboration by being aware of the challenges, (b) the best practices to provide an inventory of practices (patterns) allowing for an informed choice of practices to use when planning and conducting collaborative projects.

Method: A systematic review has been conducted. Synthesis has been done using grounded-theory based coding procedures.

Results: Through thematic analysis we identified 10 challenge themes and 17 best practice themes. A key outcome was the inventory of best practices, the most common ones recommended in different contexts were to hold regular workshops and seminars with industry, assure continuous learning from industry and academic sides, ensure management engagement, the need for a champion, basing research on real-world problems, showing explicit benefits to the industry partner, be agile during the collaboration, and the co-location of the researcher on the industry side.

Conclusion: Given the importance of industry-academia collaboration to conduct research of high practical relevance we provide a synthesis of challenges and best practices, which can be used by researchers and practitioners to make informed decisions on how to structure their collaborations.

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1. Introduction

Industry-Academia Collaboration (IAC) in Software Engineering (SE) has been an important topic since the early years of SE (around 1969). In an applied field such as SE, industrial impact of research is of utmost importance. For example, there are projects such as the ACM SIGSOFT Impact project (www.sigsoft.org/impact) which have measured and analyzed the impact of software engineering research on practice. To highlight the importance of IACs in SE, and to discuss success stories and how to bridge the gap between industry and academia, various workshops and panels are regularly organized at international research conferences, such as a panel called *"What Industry wants from research"* at the ICSE 2011 conference in which ideas from companies such as Toshiba, Google and IBM were presented. More recently an international workshop on the topic of long-term industrial collaborations on software engineering (called WISE) was organized in September 2014 in Sweden which hosted several talks on the subject.

In his classic book *"Software Creativity2.0"* [1], Glass and DeMarco dedicated two chapters to *"theory versus practice"* and *"industry versus academe"* and have presented several examples (which they believe are *"disturbing"*) on the mismatch of theory and practice.

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In a keynote talk entitled *"Useful software engineering research: leading a double-agent life"* in the IEEE International Conference on Software Maintenance (ICSM) in 2011, Lionel Briand mentioned that: *"Though in essence an engineering discipline, software engineering research has always been struggling to demonstrate impact. This is reflected in part by the funding challenges that the discipline faces in many countries, the difficulties we have to attract industrial participants to our conferences, and the scarcity of papers reporting industrial case studies"*.

To bridge the gap between industry and academia and to foster IAC, a number of researchers from academia and also practitioners from industry have systematically studied and reported challenges, best practices (patterns for successful collaborations) and anti-patterns. As the SE field matures, to ensure the relevance and impact of academic research activities, there is a major need for further IACs in this area. As the number of studies focusing on the IAC in SE has increased, it is important to systematically synthesize the state-of-the-art in this area [2–4]. Such a synthesis would provide many benefits to the broader community of researchers and practitioners, to be better aware of the challenges in collaborations and what (not) to do to ensure success. In other words, researchers and practitioners may use the results presented in this work to identify the potential risks by being aware of potential challenges, make informed decisions about what practices to utilize to ensure successful IACs.

In this work, we utilize a Systematic Literature Review (SLR) and systematic mapping (SM) process [2,5] to select the relevant studies, extract data and then synthesize the above aspects in IAC in SE.

After a careful and systematic paper selection process, our study pool included a set of 33 studies (from the set of 49 identified candidate studies) published in the area of between 1995 and 2014. The full version of our systematic mapping data is available through a publicly-accessible online repository [6]. We utilized grounded-theory-based qualitative synthesis to derive the list of challenges and best practices (success patterns) in IACs.

The remainder of the article is organized as follows. Section 2 discusses related work. Section 3 describes our research goal and research method. Sections 4 presents the results of the study. Section 5 discusses the results, and presents implications of the SLR results for researchers and practitioners, and presents the potential threats to validity of our study. Finally, Section 6 concludes this study and states the future work directions.

2. Context and related work

The context of our study is in the scope of experiences and lessons learnt about IACs as reported by SE practitioners and researchers. Since our goal is not to review nor synthesize the technical aspects of IACs reported in the literature, but instead to review and synthesize the challenges, best practices and anti-patterns of IACs, we have thus narrowed our focus to only "experience" papers reported by SE practitioners and researchers, and not the regular technical papers which have reported (empirical) applications of theoretical approaches in industrial contexts. We, as the SE community, are observing more and more papers on industrial case studies as the result IACs in recent years. There are even specific venues for such papers, e.g., the Software Engineering in Practice (SEIP) track of the ICSE (International Conference on Software Engineering), the industry track of the ICST (IEEE International Conference on Software Testing, Verification and Validation), and several recent special issues of the international SE journals on IACs.

Getting the exact statistics of technical papers in the scope of IACs in not straightforward since different keywords are used by authors in paper titles and abstracts, e.g., "industrial" case studies, "commercial". However, based on our recent experience in conducting a few bibliometric studies in SE, e.g., [7–10], we used a heuristic-based keyword to search for and get coarse statistics on the number of technical papers in the scope of IACs from the Scopus database, as shown in Fig. 1. As discussed above, we acknowledge that this simplistic heuristic-based approach is not the best way to precisely count the annual rate of papers on industrial case studies and IAC in SE, but it is a quick and rough approach to get some coarse statistics. Based on experience in our recent bibliometric studies in SE, e.g., [7–10], we searched for the word "software" in "source titles" (venues) and the phrase "industrial case" in title, abstract and keywords of papers. Given the above search query, the Scopus database returned 1577 records, which after we randomly analyzed, were a rough acceptable set of industrial case studies and IAC in SE. Fig. 2 shows the annual number of these papers and, as we can see, there has been an increase in the number of technical IAC papers in recent years.

As discussed above, since our goal in this work is to review and synthesize the challenges, best practices and anti-patterns of IACs, our focus in this work will be only on "experience" papers reported by SE practitioners and researchers, which we searched for and populated as the pool of primary studies (more details in Section 3.3.3).

Since this work is a secondary study about IAC in SE, as to the related work, we searched for secondary studies about IAC in SE, but we did not find any. A remotely-related work is [11] which is a SLR of experimental studies conducted in software industry. However, it covers no aspect of IAC.

We found only two secondary studies [12,13] about IAC in all broad areas of science. The study reported in [12] is a review of the literature on university-industry relations with respect to academic engagement and commercialization, which has been authored by a team of 13 researchers from across Europe. The study presents a SLR of research on academic scientists involvement in collaborative research, contract research, consulting and informal relationships for university-industry knowledge transfer, which the authors refer to as "academic engagement". The study reported in [13] is another more recent (published in 2015) SLR on collaborations between universities and industry. The review resulted in identifying the following five key aspects, which underpin the theory of IAC: necessity, reciprocity, efficiency, stability and legitimacy. The authors then integrated these key aspects into an overarching process framework shown in Fig. 3 which we partially utilize in the current work when we want to classify challenges and patterns over the phases of the collaboration life-cycle (from project inception to conclusion).

Overall, the related work shows that there are only limited synthesized experiences of IACs in general, and we did not identify any in the area of software engineering.

3. Method

3.1. Overview of the research method used

Our literature review was carried out in two phases. In the first phase, a systematic mapping study was performed following the guidelines by Petersen et al. [5]. The systematic mapping aimed at giving an overview of which SE topics (sub-areas) and other aspects (e.g. use of research methods) have been covered in this area. Thereafter, we conducted on the systematic review based on the guidelines by Kitchenham and Charters [2] focusing on research synthesis of the findings of individual studies to derive the challenges and patterns.

After identifying the need for the review, we specified the research questions (RQs), which are explained in Section 3.2. The

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