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Leveraging organizational climate theory for understanding industry-academia collaboration

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ABSTRACT

Context: Industry-academia collaboration (IAC) in the field of software engineering is widely discussed in the literature, highlighting its importance and benefits. However, along with the benefits, academic researchers face challenges while performing empirical studies in industry, risking their success. Awareness of these challenges and the importance of addressing them has recently grown, and became the center of discussion in several publication venues.

Objective: In this paper, we aim to address one of the key challenges affecting the success of IAC: stakeholder involvement. To this end, we propose a vision for leveraging organizational climate theory toward an effective management of IAC in software engineering research. Organizational climate is defined as the organization's priorities as perceived by its employees and was found to be an effective means of predicting employee behavior.

Method: To provide a basis and motivation for our vision, we conducted a literature review, focused on the workshop series of CESI, Conducting Empirical Studies in Industry, in order to elicit the relevant reported challenges of IAC, and to analyze them through the lens of the organizational climate theory.

Results: Emergent categories of the elicited challenges of IAC are related to the two basic components that determine the emergence of organizational climate: management commitment and communication. This result demonstrates that analyzing stakeholder involvement-related challenges of IAC through the lens of organizational climate theory provides an indication of the climate components that should be enhanced in order to address these challenges.

Conclusion: The above analysis lays the foundation for our vision that organizational climate may serve as an effective means of addressing the discussed challenges. We propose that developing measures of *organizational research collaboration climate* and deploying respective interventions for improvement would be instrumental for enhancing stakeholder involvement in IAC. We further propose a research outline toward fulfilling these potential contributions.

1. Introduction

Industry-academia collaboration (IAC) is considered to be of great importance in the field of software engineering (SE), and its advantages have been widely discussed in the literature [13,19,19,23,55]. The ACM SIGSOFT impact project [55] assessed the impact of academic research on SE practice. The project reviewed research collaborations in different SE domains, finding that SE research has significantly affected practice, and that researchers' participation has been of considerable importance [55]. As the SE field matures, in order to ensure the relevance and impact of academic research activities, there is a major need for further IAC in this area [19].

Full exploitation of the potential benefits of IAC for both parties is dependent, first and foremost, on the success of the collaboration. One of the key factors contributing to IAC success is stakeholder (practitioner) involvement in empirical research [48,88]. In fact, without stakeholder involvement in the empirical research conducted in industry, no reliable data would be available to academic researchers, rendering their research efforts void.

Our vision is motivated by the great importance of stakeholder involvement for the success of IAC research projects. Understanding the relevant stakeholders' willingness (or lack thereof) to be involved in the research collaboration, and the factors affecting it, is an important first step toward ensuring such involvement. The willingness of an individual stakeholder, operating within an organization, to be involved in—and contribute to—any activity, is strongly affected by her

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perception and interpretation of organizational expectations. Such individual perceptions, held by an organization's employees, are called the *organizational climate* [93].

Organizational climate is defined as employees' perceptions of an organization in terms of policies, procedures, practices, routines, and rewards [30,61]. Most of the current climate studies concentrate on perceptions of a specific, single facet (topic) rather than general organizational perceptions. Accordingly, the climate definition is adjusted to the specific studied facet. For example, many studies have focused on the facet of safety (e.g., [11,71,81,89,90]); *organizational safety climate* is accordingly defined as the employees' perceptions of safety in the organization in terms of policies, procedures, practices, routines, and rewards.

Climate is based on a quantitative measure that indicates whether the climate in an organization is high or low. In the example of safety, if the organizational safety climate is high, employees perceive that they are expected to behave in a safe manner; if the organizational safety climate is low, employees may perceive that they are expected to overlook safety in order to perform according to other, "more important" goals (such as efficiency). Facet-specific organizational climate was found to be an effective means of predicting employee behavior related to this facet [45].

This paper proposes that the use of organizational climate theory in the context of IAC in SE may contribute to analyzing and predicting the tendency of management and employees to be involved in the earlier stages of collaboration, and specifically during the performance of empirical studies. The development of measures of *organizational research collaboration climate (ORCC)* would provide effective means for predicting employees' tendency to be involved in, and contribute to, the planned research. By employing these measures in targeted organizations, it would additionally be possible to pinpoint potential threats, as well as to help manage the required changes for mitigating the identified threats.

The objective of this vision paper is therefore to leverage organizational climate theory for addressing one of the important challenges affecting the success of IAC: stakeholder involvement. The rationale of this proposed direction is demonstrated by analyzing a set of example challenges of IAC in SE through the lens of the organizational climate theory. Following this demonstration, a research outline is proposed toward a systematic investigation and development of relevant measures and means of fulfilling the potential of this research direction.

The paper is organized as follows. The following two sections provide the research background: Section 2 discusses challenges in IAC in the domain of SE and Section 3 presents the theoretical background on organizational climate, as a basis for the proposed vision and approach. Section 4 demonstrates the link between IAC challenges reported in the literature and organizational climate, followed by a proposed research outline for developing an organizational climate-based approach toward improving IAC, presented in Section 5. Section 6 discusses the potential benefits of this vision and proposes additional future research directions. Section 7 concludes this paper.

2. Industry-academia collaboration in software engineering

2.1. Potential benefits of industry-academia collaboration in software engineering

Many researchers agree that applying scientific research, produced in many cases by academic researchers, in industrial settings may be of great value, especially in an applied field such as SE (e.g., [13,19,23,24,55]). Perkmann and Walsh [58] define four types of university-industry research collaboration projects, which differ in their proximity to the market: problem solving, technology development, idea testing, and knowledge generation. They explain that, while problem-solving projects address issues related to products, processes, or services with high proximity to the market, at the other end of the scale knowledge generation projects make only very generic references to market-ready products or services. When university-industry relationships have more applicable objectives, such as developing or improving products, processes, or services, they involve far closer collaborations between academic researchers and industry partners than when research is initiated by academia [58].

Relationships between academia and industry come in different forms; they may be purely financial or may consist of non-financial benefits, such as access to materials or data for academic research projects or ideational inputs [58,59]. In these collaborations, the academic researcher may provide new ideas, solve problems, and propose solutions to collaborating organizations [59]. Collaborative research may include arrangements to pursue research objectives together [26], contract research conducted by universities under the direction of industry clients [50], and consulting [58].

Grossman et al. [23] studied the contribution of academic research to industry in five industries that "represent the diversity of research fields and industry structures" (ibid, p. 143). One of the important concerns that arose in that study was the ability of academic research to keep pace with the rapid changes in established firms and the ability to provide solutions and tools for nascent firms [23]. These abilities are very important for fulfilling the potential benefits of IAC.

2.2. The challenges of industry-academia collaboration in software engineering

Despite the perceived importance of IAC, the discussion in academic literature about these collaborations is not always promising. Garousi et al. [19] analyzed IAC challenges based on a systematic literature review (SLR), and found as an important challenge that research lacks practical relevance. To overcome this challenge, they suggested several best practices that include frequent knowledge transfer between researchers and practitioners, mutual engagement in formulating thesis topics, and creating a common vocabulary [19].

This challenge of practical relevance has been discussed in similar applicable fields beyond SE. For example, Fitzgerald [18] notes the perceived irrelevance of academic research to information system practitioners, and the practitioners' negative perceptions thereof. The main reason for this attitude lies in challenges related to "relevant" communication of academic research outcomes to practitioners [38], where relevance refers to applicable research findings that may be used in practical contexts to solve real and immediate problems [38,53]. In order to improve the relevance of academic research to practice, it is as important to expose researchers to practice as it is to expose practitioners to research [72]. To meet these challenges, information technology-based solutions have been proposed, for example, for communicating research outcomes to practitioners [53] and linking research and practice through regional information system knowledge networks [72]. However, given Garousi et al.'s [19] recent conclusion described above, as well as the additional challenges listed below, it is clear that these challenges are yet to be effectively addressed.

IAC challenges stem from the substantial differences in the goals of academia and industry. These differences must be communicated and fully understood by all parties involved [88]. Researchers must accept that industry deadlines and budgets override most other issues [88], and practitioners should be aware of the importance and contribution of academic research to the SE domain [69]. The challenge is therefore to find ways of working within these boundaries and to address the problems this may create [88].

Working within these boundaries would require, for example, requesting employees to invest as little time as possible in the research, since they are busy with their duties [8,15,70]. To overcome this challenge, academics frequently attempt to find means of adapting the academic research settings to the industrial reality. The solutions proposed in the literature suggest integrating the research into the daily work. For example, Rodríguez et al. [63] discuss the advantages of design science as a suitable research framework for empirical SE research. Design science research facilitates mutual learning, the

integration of research activities in the company's daily work, and relatively quick and progressive gathering of empirical data, as well as the participants' understanding of the research approach because of its similarity to their day-to-day work. A similar strategy to relate practitioners to research by using familiar industrial concepts is offered by Misirli et al. [51], who propose leveraging agile and lean values to strengthen the argument for experimentations, or to leverage the training angle, accepted in industry, for aligning research and industry interests. Dieste et al. [15] suggest that experiments should not be presented or allowed to be conceptualized as extra work. Whenever possible, the company should be able to use the experimental results directly, for example, those of an inspection experiment run using the software specifications of the ongoing project. Another possibility is to design the experiment as a practical part of a training course.

An additional challenge is related to the alignment of the research with the business goals of the industrial partner. Dieste et al. [15] suggest that experiments should be run on topics that are directly useful to the company. Negotiation with the company in pursuit of a win-win situation is the best possible alternative, but business goals take priority, and researchers should fit in with this constraint.

Importantly, even when these win-win situations are achieved and upper management provides clearance for the researchers to pursue the research, it is not enough to grant the researcher access to the company's sites and employees; the researchers also need buy-in from relevant lower-level managers [57]. Direct managers and employees need to be convinced of the importance and benefits of the empirical studies in which they are requested to participate [21,39,60,88].

Garousi et al. [19] performed an SLR focusing on the challenges, best practices, and anti-patterns of IAC. In their work, they included 33 primary studies reported by software practitioners and researchers. The key challenges reported in their study were classified according to IAC lifecycles phases [19]:

Problem formulation phase: The formulation of the research problem and the agreement on collaboration, including key challenges related to the differences between the industrial and the academic partners, in terms of time horizons, objectives, reward systems and perceptions of what is useful.

Planning phase: The definition of research-specific objectives and time planning. In this phase, also, the time horizons are a key challenge, mostly because of the misalignment between the short-term goals of the company and the long-term goals of the research. Another key challenge is related to the limitations imposed by planning in order to achieve highly valid research results on the one hand, and the challenge to achieve clear and realistic goals in the company's projects, on the other.

Operationalization phase: The execution of the research. The main challenges presented in this phase are the lack of available resources from both industry and academia partners and validity concerns that need to be addressed when industry is involved, because of the influence of context as a confounding factor.

Transfer and dissemination: The application of the research results in the field and publication thereof in academic literature. The key challenge discussed here is that research results are sometimes too abstract or toy example-based to be exploitable on an industrial scale. Moreover, because of the loss of champions in projects over time, dissemination becomes difficult without the initial dedication of the champion.

The challenges with which SE researchers deal when performing empirical research in the field have been discussed from various angles at different venues, including, for example, an international workshop series CESI—Conducting Empirical Studies in Industry,[1] and an international workshop series WISE - Long Term Industrial Collaboration on SE.[2]

[1] http://cesi-workshops.org/.

[2] https://www.sigsoft.org/resources/opentoc/WISE2014-TOC.html.

The reason the challenges of IAC have been gaining so much attention is their potential to hamper empirical research conducted in industry, which may result, for example, in additional large efforts of researchers to collect data from reluctant participants, reduced validity of research findings and conclusions because of partial or unreliable data, and even an utter failure of the research project. It is therefore very important to identify, assess, and mitigate challenges and risks as early as possibly in the collaboration. It is also important to acknowledge the unique nature of the SE domain, and the challenges and risks stemming directly from this nature. Research on IAC in SE is relatively young, and for the most part produces reports on the challenges of such collaborations without explicitly distinguishing between any IAC challenges and the ones specific to this domain. Toward assessing the readiness of an organization for a collaboration with academic researchers through the lens of organizational climate, it is important to account for the all potential challenges, both those generally related to IAC and those stemming from the specific attributed of the SE industry.

3. Organizational climate

3.1. Organizational climate theory

The literature on organizational climate suggests that the organizational environment has a strong influence on employees' perceptions and behavior [75]. The organizational environment introduces this influence in the forms of organizational culture and organizational climate. Organizational culture is defined as the shared values and basic assumptions of a group, and is distinct from the concept of organizational climate, which focuses on shared perceptions [68]. While both can be changed over time, it is more difficult, and requires a longer time, to change culture than to change climate. Therefore, the use of the organizational climate concept has grown in applied psychology in comparison to that of organizational culture.

Several assumptions underlie the organizational climate theory: (1) employees behave according to the way in which they perceive their organizational environment (including policies, procedures, practices, etc.); (2) the perceptions of the organizational environment are an outcome of a social process that is based on the interaction and communication of employees with managers and with each other; (3) the perceptions of the organizational environment are facet-specific; that is, employees have perceptions separately for each topic or facet to which organizational policies, procedures, and practices refer; and (4) these facet-specific perceptions help employees understand the relative importance of each facet and thereby make sense of what is expected of them.

Organizational climate captures the "sense of imperative," the perceived importance of a facet to members of the group [45]. The oldest explanation for the emergence of such a sense of imperative is the top-down processes in organizations, first explored in Kurt Lewin's studies [41], which focused on the leader as important influencer on group climate. Many studies followed this approach, focusing on managers as highly influencing climate (e.g., [3,10,33,42,44,80]). Zohar and Luria [93] suggested that the top-down process is hierarchical, starting from the management level commitment to the topic under research, which is transferred to the department level managers and finally to the operation-level employees. They demonstrated that management level commitment can be captured by incidents that indicate to organizational members the importance of the facet (in their study, safety). They also demonstrated that in organizations where employees perceive that the management is committed to safety, the employees behave accordingly in a safe manner.

Specific facets (topics) of organizational climate have proven effects on employee behavior (e.g., [12,54]). Facet-specific organizational climate refers to shared perceptions, held by members of an organization, regarding aspects of the organizational environment that communicate what behavior—related to this facet—is rewarded and

supported by the organization, and to what degree [93].

The concept of organizational climate has recently been explored, to some extent, also in the domain of SE, for example, the facet of knowledge sharing among programmers [79] and the facet of information privacy in software development organizations [25].

3.2. Organizational climate measures

Organizational climate level is determined via designated measures developed uniquely for a given facet. Climate measures typically focus mainly on two overall dimensions: (1) Do employees perceive that the *management's commitment* is high, based on its actions (the practices, procedures, and policies enacted by management)? (2) Is the importance of the facet (topic) *communicated* to the employees by managers?

The development of climate measures requires the development of designated surveys focusing on reported actual behavior and perceived expectations in the context of the measured facet of organizational climate. In order to understand employees' perceptions regarding a specific facet of climate, some items in the survey should present operational demands competing with other facets. For example, caring for work safety reduces productivity; therefore, employees will perceive that safety is important if management is committed enough to safety such that managers agree to a slower production pace in order to reduce risks [89,90].

These measurement scales are designed to capture a coherent entity, building on the concept of "Gestalt" [41]. It is not the individual climate item that stands alone and captures the concept, but rather the aggregation of the full set of climate items. In other words: "climate is a gestalt, a whole that is constructed and can be identified based on specific activities, behaviors, and experiences" ([65]; p. 28).

Climate measures were proven to be relevant to a variety of settings. For example, in the context of safety climate, Zohar [89] was the first to measure climate in manufacturing industries, followed by many others (e.g., Huang et al. [27] in transport organizations). This scale has also been adapted for other types of social structures, such as the military [42,44] and safety in communities [46] and in family settings [78]. The literature provides evidence that individuals' perceptions about practices and policies in their group can help to capture the relative importance of a facet for that group in multiple settings and industries. Items in a climate questionnaire should capture indicators of importance that are relative to the industry, organization, and settings under research.

Zohar [89] describes the development of a focused safety climate measure including employee perceptions of management attitudes toward safety and the effects of safety behavior on promotion and status within the organization. This measure was found to be significantly correlated to safety inspectors' rankings of organizations' safety practices and accident prevention programs. Luria [43] proposes a measure for organizational quality climate, calculated based on employees' perceptions of quality assurance policies and practices, and their managers' reactions to quality related behaviors. Similar measures have been developed for organizational climates related to service, justice, leadership, and more [67].

Organizational climate measures were found to be predictive of employee behavior in a variety of facets. For example, studies on work safety found that organizations with high levels of safety climate report fewer injuries than organizations with low levels [7,11,20,22,71,81,90].

Mohamed [52] corroborates the importance of management commitment, communication, and workers' involvement, attitudes, and competence, as well as supportive and supervisory environments, to achieving a high level of safety climate. Studies that investigated organizational ethics as an aspect of organizational climate similarly examined the effect of the ethical climate on employee behavior. Organizations with a high level of ethical climate were found to contribute to employee ethical behavior [4,14,28]. Supervision was found to strongly influence ethical climate and ethical behavior [87]. Overall, while different papers on different facets of climate mentioned a variety of components, the two reoccurring and central themes that emerge as climate components are *management commitment* and *communication*. Employees perceive that a facet is important in their organizational environment based on communications of explanations regarding the facet and actual indicators demonstrating the managers' commitment to it. For example, Zohar and Luria [92] distinguished two basic components: communication in the organization (e.g., declarations made and distributed within the organization) and the events indicating actual managerial commitment (e.g., implementation of relevant practices).

3.3. Leveraging organizational climate theory for industry-academia collaboration

The role of organizational climate in the context of collaboration of research and practice has been examined in several domains thus far, most notably that of healthcare (e.g., [1,2]). These studies focused on a single-facet climate predicating the extent of evidence-based practice (EBP) implementation, namely employees' tendency to behave according to insights and innovative solutions stemming from research. These studies demonstrated that in organizations with a high EBP climate, employees perceive that EBP is considered important, understand that collaboration is expected of them, and behave accordingly.

Kitchenham et al. [37] examined how SE might benefit from an evidence-based approach and what potential difficulties are associated with this approach. They compared the organization and technical infrastructure supporting evidence-based medicine with the situation in SE, and concluded that evidence-based SE (EBSE) promises a number of benefits by encouraging integration of research results for supporting the needs of multiple-stakeholder groups. At the same time, the authors note that the infrastructure needed for widespread adoption of EBSE is not yet in place. Specifically, the skill factor means that SE experiments are vulnerable to subject and experimenter bias, and the lifecycle factor means that it is difficult to determine how technologies will behave once deployed. Kitchenham et al. [37] claim that SE would benefit from adopting what it can of the evidence-based approach, provided that it deals with the specific problems that arise from the nature of SE. Importantly, unlike in the previously cited papers on EBP, here organizational climate theory was not part of the discussion.

The industry-academia research collaboration facet proposed in this paper focuses on collaboration in the sense of stakeholder involvement in empirical research. We expect this facet to demonstrate characteristics similar to those of the facets described above, by competing with other goals that are typically perceived as having higher priority, such as productivity. Since organizational climate in the context of IAC in research has thus far not been examined, we believe that valuable lessons can be learned from previous research studies examining the change in employees' behavior via other facets of organizational climate.

Based on the above, it is reasonable to infer that designated measures of the research collaboration climate facet of an organization would be quite predictive of its employees' behavior. The components that were found to affect organizational climate, such as management commitment and communication with employees, need to be considered when forming the new construct of *organizational research collaboration climate* (ORCC).

Fig. 1 illustrates the process of organizational climate emergence, focusing on ORCC. According to the theory of organizational climate, one can analyze the social organizational processes that can explain, and predict, the success of IAC. The process starts from an objective organizational environment that is constructed of policies, procedures, and practices. Different policies, procedures, and practices are relevant to different facets in the organization. Managers and employees interact in order to understand this environment and make sense of what is

Fig. 1. Process of organizational research collaboration climate (ORCC) emergence.

expected of them (i.e., the sense-making process). Based on this interaction, subjective climate perceptions emerge that guide the behaviors of employees. In this case, the level of the emerging ORCC, and its relative importance in light of other—potentially competing—goals, determines the actual collaboration of employees with the empirical research. Measurements of this climate level will allow the expected level of employees' involvement in the empirical research to be predicted.

4. Analyzing reported challenges of industry-academia collaboration through the lens of organizational climate theory

4.1. Overview

In this section, we review reported challenges and risks in empirical SE studies in industry, focusing on case-study research studies, which are the ones in which we suggest that organizational climate may play a role. We list the challenges and risks that we deem to be related to the concepts of organizational climate. Note that we do not present a saturated list of all challenges; rather, we demonstrate that a subset of the research collaboration-related challenges discussed in the SE literature can be interpreted through the lens of organizational climate theory. For the purpose of this demonstration, we included in our review below the papers published in the four editions of the CESI workshop (2013–2016). Importantly, only the challenges we considered to be related to organizational climate are listed below; this is not to say that they are more important than other challenges, but rather that these are within the scope of this paper.

The review of the CESI papers resulted in a list of elicited challenges. We started the analysis of these challenged by grouping them into emergent categories, based on open coding principles [76]. Then, we turned to the organizational climate literature for guidance for further analysis of these categories (consideration of literature is allowed when applying grounded analysis [74,77]).

Organizational climate emerges in a top-down process in which managers have a central role [3,10,33,41,80]. The top-down process of communicating the climate to the organization's members is hierarchical, starting from the *management level commitment* to the climate facet, which is communicated to the department level managers, and finally to the employees. These *communications* indicate to organizational members the importance of the facet, thus affecting employees' perceptions of what is valued and rewarded by the organization with regard to the specific facet, and thereby ultimately affecting their behavior [93].

Accordingly, we focused on the two basic components that determine the emergence of organizational climate regarding the facet, management commitment and communication, aiming to map each emergent category to one of these two components. Several categories could not be mapped inclusively to one of the two components, because they reflected both. These categories were therefore mapped to the combination of the two components—management commitment and communication.

4.2. Challenges related to management commitment

Management commitment refers to the actual behavior of management that promotes and transforms the importance of the facet to actions. For example, the actual investment of resources in activities that promote the facet, undertaking structural changes in the organization, and giving power to a manager who serves as the champion of the topic that is related to the facet [93].

Table 1 demonstrates a mapping of challenges reported in the CESI papers to the component of management commitment. Within management commitment, we include the following categories that emerged from the elicited challenges: *management*, which includes observations indicating challenges and risks manifested in the actual behavior of the upper management; *champion,* the manifestation of management commitment via a designated person responsible for promoting and supervising the research project; and *resources*, the concrete outcome of management commitment translated to the actual effort invested in the research project.

While many of the challenges presented in Table 1 are possibly generalizable to domains beyond SE, some aspects related to this specific domain should be taken into consideration. For example: accessibility to documentation may be hampered not only by lack of collaboration, but also because of the typical problem of lacking or obsolete software documents [32,40]; an organization champion may have limited influence on the self-organizing autonomous development teams, requiring perhaps local champions, such as the scrum master who is responsible for ensuring that the team complies with the defined

Table 1
Challenges related to *management commitment* to the research collaboration.

Challenge related to	Observation	Source	Evidence from
Management	It is important that the commitment comes from the manager actually responsible for the resources to be used in the collaboration.	Wohlin [88]	Author's research experience
	Upper management's initial agreement to give access to documentation does not promise its realization in practice.	Lavallée and Robillard [39]	Exploratory observational case study
Champion	A champion is the main driver of the collaboration on the industry side, committed to facilitating and contributing to a successful collaboration.	Wohlin [88]	Author's research experience
	Case studies can be driven only by motivated project participants who are ready to invest additional effort in collecting data.	[21]	Authors' research experience
Resources	Companies are reluctant to engage in non-productive (or non-billable) time-consuming activities.	Dieste et al. [15]	Systematic literature review
	Management is anxious to minimize interference with the normal activities of the software development team.	Lavallée and Robillard [39]	Exploratory observational case study
	Managers and employees perceive the research as a waste of time.	Sherman and Hadar [69]	Long-term case study
		Jain et al. [29]	Analysis of a selected set of studies the authors conducted
		Vegas et al. [82]	Running an experiment in several companies
	A misalignment of the industrial participants' requirements and the requirements of conducting systematic and rigorous research.	Jain et al. [29]	Based on analysis of a selected set of studies the authors conducted
	Companies lose motivation to cooperate once their main purpose of the research has been achieved, even though research rigor has not yet been achieved.	Sherman and Hadar [69]	Long-term case study
	There is a reluctance to provide access to employees without reasonable assurance of benefits.	Misirli et al. [51]	Industry experiments in six software development organizations
	It is more difficult to recruit, at a single organization, 12 people to participate 3 h each than to recruit 3 people to participate 12 h each, because these people need to be found, their concerns addressed, and their time constraints accommodated.	Prechelt et al. [60]	Authors' research experience plus an additional empirical researcher's experience.
	It is important that the industry provides the necessary resources in terms of people, software/hardware, and rooms.	Fernández and Wagner [17]	Analysis of 30 case studies conducted by the authors
		Karim et al. [34]	Industrial case study

Table 2
Challenges related to communication about research collaboration.

Challenge	Observation	Source	Evidence from
Trust and respect	It is important that all parties involved trust and respect each other, and that the mutual benefits of having different strengths become clear to the individuals involved.	Wohlin [88]	Author's research experience
	The importance and potential contribution of the research is not evident to the practitioners, resulting in general distrust.	Shreman and Hadar [69]	Long-term case study
	Establishing trust takes time.	Misirli et al. [51]	Industry experiments in six software development organizations
	Since the study is added on top of practitioners' normal work, it is important to convince them how this study will benefit them.	Fernández et al. (2016)	Analysis of 30 case studies conducted by the authors
Terminology	Using academic terms, e.g., experiments or research, highlights the academic benefit more than the industrial one.	Dieste et al. [15]	Based on systematic literature review
		Sherman and Hadar [69]	Long-term case study
	Training both practitioners and researchers toward the domain, terms, and techniques of the other team would contribute to maintaining better communication.	Karim et al. [34]	Industrial case study
Researchers' accessibility	It is important that the researchers feel comfortable enough to walk around and knock on doors and to go to joint lunches and coffee breaks, participate in relevant meetings, and have access to other data sources, such as computer systems, software, and databases.	Wohlin [88]	Author's research experience
	There are problems in fluent and direct communication among employees and researchers.	Martinex-Fernandez and Marques [48]	Multiple-case studies

process [5]; the actual resources accumulate to more than the time required from employees to invest in the research, because of overheads related to task interruptions in the context of the specific nature of software development tasks [9,49,56]; and the effect of Brooks' law on the distribution of the effort between employees [6], making participation of a few investing much effort more economical than the participation of many investing little effort.

4.3. Challenges related to communication

The communication component of the emergence of organizational climate is often discussed and explained according to the sense-making approach. Sense-making focuses on the way employees give meaning to their organizational experiences [84], and is important because of the high complexity of the organizational environment . Some of these signals may concern the importance of a facet and therefore help employees reach consensus regarding this importance [92].

Discussions within each unit about organizational experiences and its members' interpretations of these experiences can explain why different facet-specific climates emerge in different organizational units [42]. A meta-analysis indicates that group-level processes are central in the emergence of climate [10]. Such processes include coordination, cooperation, and communication [35,36]. Luria [44] demonstrated that managers' ability to influence climate depends on their level of trust

Table 3
Challenges related to the overlap between management commitment and communication with regard to research collaboration.

Challenge	Observation	Source	Evidence from
Participation	While upper management was interested in the research, it was not enough to ensure the participation of the developers in the collaboration project. The teams had their own managers, not all teams were open to the change and motivated to participate.	Wohlin [88]	Author's research experience
	Subjects may regard the treatment as ineffective and therefore pay less attention. Effective training time is shortened in these situations. Subjects' perception of training has a marked and almost immediate effect on motivation.	Vegas et al. [82]	Running an experiment in several companies
	It tends to be much more difficult to obtain the participation of 4 developers, 2 testers, 1 architect, and 1 team lead than it is to obtain participation of 8 developers, because convincing them that participation is worthwhile works differently for each type.	Prechelt et al. [60]	Authors' research experience + an additional researcher's experience.
	A team assigned to the study by some boss (as opposed to deciding themselves) will not remove the role-diversity difficulty, because without convincing the team members, data collection may not actually be performed effectively.		
	The case study might have been delegated to someone not interested at all in the study.	Fernández et al. (2016)	Analysis of 30 case studies conducted by the authors
	It is important that practitioners collaborate with researchers when defining deliverables and responsibilities.		
Knowledge about research	It is important to differentiate the experimental approach from other validation strategies used in industry.	Misirli et al. [51]	Industry experiments in six software development organizations
	It took time to realize that the researchers were not there for consultancy.	Ribeiro and Travassos [62]	Industrial case study
	Practitioners tend to misunderstand what an experiment is.	Vegas et al. [82]	Running an experiment in several companies
Individuals' concerns	Practitioners may be concerned that data from their participation in the research, or the outcome of the research in general, would harm them in the future.	Sherman and Hadar [69]	Long-term case study
		Čaušević et al. [8]	Case study
		Lavallée and Robillard [39]	Exploratory observational case study

with their subordinates. Trust is an essential factor in communication [16] and is therefore central in the sense-making process in which managers explain the importance of a facet to an employee. Sense-making processes involve processes of social construction, in which group members try to interpret confusing signals by interacting with each other [31,64,85]. This involves creating short narratives of the experienced phenomena [83] and therefore many studies on sense-making processes focus on the terminology employees use in their communication of the facet.

Table 2 demonstrates the mapping of challenges reported in the literature to communication. Within this component, we include the following categories: *trust and respect* between management, researchers, and employees, which is a core principle of successful communication and has an influence on productivity and utility of the outcome; *terminology*, which has a key role in sense-making communications between the different stakeholders; and *researchers' accessibility,* which refers to researchers being able to easily communicate with employees and thereby have access to relevant resources.

The challenges related to *trust and respect* and *terminology* may be relevant for any domain and are not necessarily specific to SE. In the context of *researchers' accessibility*, however, researchers' limited accessibility to employees may not stem only from poor collaboration intentions of the latter; it may alternatively—or additionally—stem from the routine development practices in this domain that include many meetings and unplanned activities, reducing employees' availability. These can hinder fluent and direct communication, even in cases where employees are willing to invest their best efforts to collaborate with the researchers and participate in the empirical studies. On a more positive note, ever since agile development has become widespread and the emphasis in development processes moved to individuals and interactions over processes and tools,[3] communication in general has become an important and respected facet in SE.

[3] http://agilemanifesto.org/.

4.4. Challenges related to the combination of management commitment and communication

Table 3 demonstrates the mapping of reported challenges that correspond with both management commitment and communication. Employees' willingness to collaborate with researchers and *participate* in empirical studies depends on the managers of different levels and their own commitment to the research which, in turn, depends on how this collaboration is communicated in the organization. *Knowledge* about the research is also related to an overlap of management commitment and communication, since it requires management first to obtain the relevant knowledge and then to communicate this knowledge to employees. Employees are then expected to learn and give meaning to this knowledge in the organizational context via sense-making processes. Finally, management should be aware of and respect *employees' concerns* regarding the research outcomes, address them, find means to mitigate them, and communicate these means to the employees.

It seems that most of the challenges presented in Table 3 are general to various domains beyond SE. One example of a challenge that stems from the specific practice of SE is knowledge about experimentation. Misirli et al. [51] observed a misunderstanding, demonstrated by industrial partners, of the differences between the experimental approach and other validation strategies used in the industry, such as feasibility evaluations and pilots conducted for validating new software technology.

5. Proposed research outline

5.1. Vision

IAC is typically enabled after the industrial partner's management has expressed support of the study; alas, this support does not suffice for engaging employees and relevant stakeholders in the study, as reported by many researchers (e.g., [21,39,57,60,88]). Our vision is that

leveraging organizational climate theory, and specifically developing measures of *organizational research collaboration climate* (ORCC), as well as interventions for improving this climate, would be instrumental for enhancing stakeholder involvement in IAC.

The measures and interventions proposed in the literature on organizational climate offer a promising direction for developing effective means of identifying the gap between the importance of the research collaboration as perceived by management and the related organizational climate. Examples of existing climate measures include measures of safety climate [93], quality climate [43], and service climate [65]. These measures provide quantified values regarding the employees' perceptions of the priority of the climate facet (i.e., safety, quality, and service) in the organization and what is expected of them with regard to this facet. Such facet-specific organizational climate measures were found to be effective in predicting employee behavior related to the facet [45].

Once identified and analyzed, the gap between management perception and organizational climate regarding a certain facet may be bridged by respective interventions designated for bringing about the change in the organizational climate, in order to improve employees' perceptions as to the importance of the facet and the behavior that is expected in this respect (see Luria's [45] recent review). Examples of such supervisory-based interventions that aim to change climate include workshops for supervisors on safety leadership, personal feedback, and coaching regarding managerial safety practices [47,91,94].

The proposed research will aim at developing relevant measures for ORCC, and respective interventions, based on existing methods of developing climate measures, some of which are briefly described above in Section 3.2. Using these measures prior to engaging in such a collaboration would enable academic researchers to predict the level of employee involvement they can expect from their industrial partner. Given low predicted involvement, the researchers would be able to choose together with the organization's management one of the following options. (a) Initiating change in the ORCC, and kicking-off the collaboration only if and when a high level of this climate has been achieved. Proposed interventions and guidance to their implementation could be beneficial for achieving an increased level of ORCC. (b) Canceling the planned research collaboration before further efforts are invested in it, because of its low success prospect; for example, in the case where management commitment is not high enough to facilitate a change in the organizational climate.

Pursuing the proposed vision would have the following contributions. First, it would provide effective means for managing such IACs, by measuring and improving ORCC and controlling it over time. Second, no more effort will be invested in collaborations having no hope of success. The climate measures will serve for identifying high-risk collaborations, enabling the researcher to take informed decisions as to the initiation of collaboration with a certain industrial partner.

5.2. Research roadmap

The proposed research is motivated by the potential benefit of leveraging organizational climate theory for understanding, and possibly improving, IAC. The main objective of the research is to define appropriate organizational climate measures and guidelines for interventions in order to enhance IAC, and specifically stakeholder involvement in empirical research.

The main research questions derived from this objective are the following:

RQ1: What are the challenges of IAC in SE?
RQ2: What are the typical organizational goals interacting with and affecting the research collaboration climate facet?
RQ3: What climate measures can be developed to evaluate the organizational research collaboration climate?
RQ4: What interventions can affect the organizational research collaboration climate?

A research plan guided by the above objective and questions should draw knowledge from both domains: empirical SE research in industry and organizational climate theory. Fig. 2 presents the proposed research roadmap, showing the two respective bodies of knowledge, research activities, their sequence and dependencies, and the outcomes of the research, including climate measures and intervention guidelines.

The body of knowledge of empirical SE research in industry includes papers describing the challenges and the lessons learnt in this context.

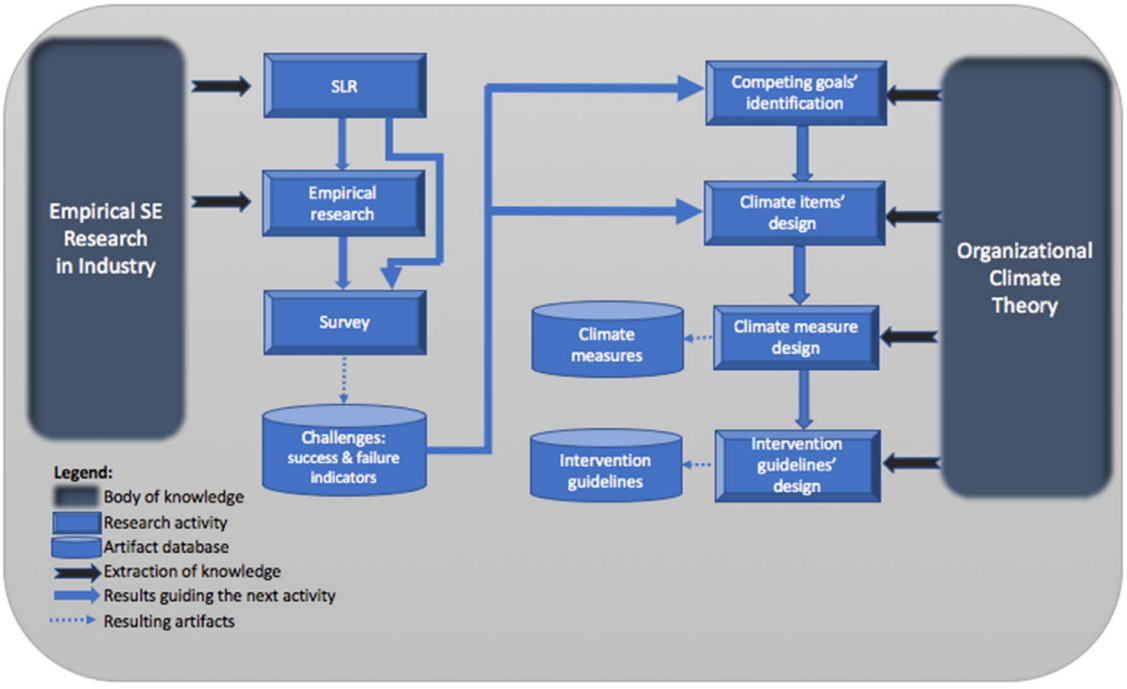

Fig. 2. Research roadmap.

These papers present different types of evidence, as demonstrated in the previous section. An SLR, focused on the organizational aspects related to IAC, should identify all relevant papers and result in a comprehensive list of challenges based on this review, while taking into consideration the reliability of the reported challenges and the evidence on which they are based.

The proposed SLR research may suffer from the following limitations. (1) Limited number of existing papers, especially those presenting empirical evidence. A recently published SLR [19], focusing on challenges and best practices in IAC in SE, included 33 papers related to this topic, noting that: "Only a small ratio (5 out of 33) are rigorous empirical studies on IACs." (2) In many papers, the presentation of observations regarding research collaboration is only a by-product of a research study focused on a different objective. This results in sporadic, and for the most part, anecdotal insights and conclusions, rather than in a systematically constructed body of knowledge gradually built on the basis of previous research.

In light of the above limitations, we propose to strengthen the basis of this research by engaging in a more systematic empirical research program, in order to achieve a comprehensive and reliable list of IAC challenges. As this research will aim at exploring and revealing challenges, especially those not yet identified in earlier studies, rather than corroborating existing ones, a qualitative research approach is required [73]. Such qualitative research studies can be conducted, for example, as an analysis of case studies of research collaborations between industry and academic researchers.

Upon achieving a saturated list of challenges, we propose to corroborate each of these challenges using quantitative tools, i.e., via surveys. The distribution of questionnaires among SE researchers collaborating with industry and among practitioners in companies in which academic research is being—or has recently been—conducted, would enable to substantiate whether, and to what extent, each of the challenges is evaluated by practitioners and researchers in terms of playing a role in determining the success of the collaboration. This research activity, concluding this part of the research roadmap, is expected to result in a saturated and validated list of challenges.

The second part of the research roadmap would involve designing climate measures and interventions, guided primarily by organizational climate theory literature. Based on the validated list of challenges, climate items can be derived and the respective measures defined, followed by the development of respective interventions.

The literature on organizational climate presents a vast amount of guidance for developing organizational climate measures and interventions. For example, Schneider et al. [66] proposed a process in which items of climate scale can be developed and implemented for developing the service climate scale. This procedure was later adopted by others (e.g., [46]). Schneider et al. [66] suggested that qualitative indication of the importance of a facet in the organization or the group can be translated into climate items that allow the investigated phenomena to be measured quantitatively. They further suggested that through using qualitative data collection procedures, such as interviews and focus groups, one can learn about indicators for the importance of a facet as the employees perceive it. Based on content analysis of the qualitative data, it is possible to develop a list of indicators of facet importance that can be translated into climate items, thus facilitating quantitative measures.

For example, an employee can report in the qualitative analysis that a facet is important because the organization's training procedures include some mandatory training regarding aspects of this facet. Based on this, the following climate item can be developed: *organization invests in training regarding the facet*. Another example can be structural: employees may indicate that they think that a certain facet is important because the manager responsible for that facet has influence and authority in the organization. The following climate item can accordingly be developed: *management nominates an influential manager to improve the facet*. Examples of climate items can also be presented regarding lack of importance. For example, the management of an organization may declare that a facet is vital, but employees perceive that when improvements in this facet require financial investment or delay in production, these improvements are not implemented. Such a reverse item can be, for example: *management is not willing to invest money in improvements relating to the facet in the organization*.

Based on the answers (given on a Likert scale) to a list of items regarding the investigated facet, a climate level score is calculated by aggregating the answers of all the items of all the employees within the same organizational unit and calculating an average. This average (also known as climate level) provides a simple feedback that indicates the perceived importance of the facet in the organization. Based on this information, management can understand whether there is a gap between the importance of the facet as perceived by management and the level of its climate within the organization. Management can measure the climate level before and after interventions aimed to improve the facet, to obtain an indication of the effectiveness of the intervention and to make improvements until the importance of the facet and the organizational climate regarding this facet are aligned. These means are also important for sustaining this alignment.

Several candidates for relevant climate items and their respective interventions can be derived from the process proposed by Schneider et al. [66] (see Section 3.2). For example, a climate item could probe whether *a champion with influence and authority in the organization was nominated to promote the research project*. This item should be measured via a questionnaire, requesting that employees score their agreement level on a Likert scale. Should this item's measurement return a low value, an appropriate intervention could be to nominate such an influential champion (whether because such a champion did not exist, or because the existing—not influential—champion needs to be replaced).

The viability of this line of action can be demonstrated by evidence provided by existing SE literature on IAC. Let us examine, for example, the following three climate items, based on the items proposed by Zohar and Luria [93].

(1) *Champion: Appointment of a champion with influence and authority to promote the facet.* The importance of champions and their influence on the success of IAC have been acknowledged in the SE literature. For example, Wohlin [88] states that a champion, committed to facilitate and contribute to a successful research collaboration, serves as the main driver of the collaboration on the industry side. Fernández and Wagner [17] further explain that working with a champion "with an intrinsic motivation at project level and reflecting her own needs and interests in the study opens many doors which otherwise might remain closed."

(2) *Resources: Management is willing to investment resources (*i.e.*, time and money) for improving the facet.* Indeed, the resources available for performing a study in the SE industry play an important role [34]. An empirical study in industry has to be planned in detail and include a time and resource plan, and accordingly, people, software, hardware, and rooms need to be allocated by management [17]. Evidence from the field demonstrates the challenges to performing empirical studies in the SE industry when needed resources are not allocated by management. For example, Sherman and Hadar [69] reported a research study that was not completed, because top management discontinued its investment of time and human resources for the study, once the management's desired study outcomes had been provided [69]. On the other hand, Karim et al. [34] reported a successful research study in an industrial company, in which the needed resources were allocated throughout the study.

(3) *Competing goals: Top management considers the climate facet when setting production speed and schedules.* In other words, this item indicates whether management prioritizes the facet at hand over the classical need for production efficiency. This item and its influence have also been discussed in the context of empirical research in the SE industry. For example, Dieste et al. [15] noted that "the

companies are reluctant to engage in non-productive activities in the current scenario of economic recession." Lavallée and Robillard [39] reported a study that seemingly received top management's full support. However, when it came to the actual study execution, management remained anxious to minimize interference with the normal activities of the software development team.

The above demonstration shows promise as to the feasibility of developing effective organizational climate measures and interventions adapted to the context of empirical study in SE. Such measures and interventions have the potential to explain and improve the ORCC, which would in turn improve the actual behavior of employees, namely, their involvement in the collaborative research.

We propose that the first step should be to validate a climate scale for IAC by measuring it in multiple organizations and correlating it with the expected outcome (employee participation in the research). If, as expected, a positive correlation is found between IAC climate and employee participation, this step would demonstrate that the climate approach is relevant to the IAC in SE research. Such a valid scale would provide a measure indicating organizations in which collaboration would be problematic. The second step should be to demonstrate that, based on the climate approach, IAC can be improved. This could be done by studying supervisory-based IAC interventions that should improve climate perception and actual participation in IAC.

Accordingly, the following two hypotheses will be examined:

Hypothesis 1. Industry-academia collaboration climate level will be positively correlated with employee collaboration and participation in academic research activities.

Hypothesis 2. Interventions aimed to improve managerial commitment and communication regarding industry-academia collaboration will be positively correlated with the level of the employees' climate perceptions of industry-academia collaboration.

Importantly, these hypotheses cannot be tested via experimentation in the lab. Organizational climate emerges naturally over time within organic organizational units, groups, or teams. The climate approach can therefore be tested only in natural settings within organizations, where climate measures and interventions are used and tested over a long period of time.

6. Discussion

Many of the IAC challenges discussed in the SE literature are related to stakeholder involvement in the empirical studies. In Section 4, we demonstrated how challenges related to case study research in the SE industry can be mapped to components of organizational climate. Reflecting on proposed practices for addressing some of these challenges, we see some correspondence with the principles of organizational climate, as discussed below.

Garousi et al. [19] performed an SLR, and, based on the analysis of the studies in their review, propose the following key best practices.[4] In the *problem formulation phase,* appropriate presentation and communication of the research topic and investment in understanding the problems of the industry to gain the industrial partner's commitment using systematic research approaches, are needed. These proposed practices correspond with both the management commitment and the communication components of organizational climate. In the *planning phase,* Garousi et al. [19] indicate that the best practice frequently used in the reviewed studies was achievement of common objectives, and a common understanding of the research, with the industrial partner. This includes early agreement on mutual goals, roles, and time horizons. These practices correspond with the component of management commitment. In the *operationalization phase* and the *transfer and dissemination phase,* Garousi et al. [19] propose that key benefits need to be shown and demonstrated to the industry partner and that the researcher should be collocated at the company and regularly be present, thus striving for, in the terms of ORCC, management commitment as well as employees' trust and respect via ongoing communication. In these phases, the authors also propose to focus on solutions based on real-world problems observed in industry and identify specific quality attributes of solutions that should be fulfilled. These practices correspond with management commitment and strive to overcome the widely discussed challenge of the relevance of academic research to practice (see Section 2.2).

The knowledge constructed regarding organizational climate has changed the structure of organizational interventions aimed to improve performance in organizations. While previous interventions were directed to employees, supervisory-based interventions were developed based on the climate theory [47,91,94]. These interventions demonstrated that it is more effective and efficient to change the communications and commitment of the managers regarding a facet than to work directly with the employees. Changing managerial patterns that will demonstrate and communicate well the importance of a facet will create a high level of climate regarding the facet that will eventually be translated into the employees' behavior and performance. These interventions are based on focused work with a small group of managers (instead of a large group of employees), training them to communicate the importance of the facet frequently and raise the managers' awareness of actions that demonstrate strong commitment to the facet. For example, managers are trained to observe when the facet conflicts with other facets and to try to give the promoted facet clear priority over the competing facets and to communicate to employees the choice they made.

A high level of ORCC is a necessary but not sufficient condition. In addition, the climate related to the specific topic on which the research is focused is a complementary component for facilitating successful collaboration. Consider the following anecdotal example from our own experience. In the context of a long-term research project we conducted in a large IT company, with which we had a fruitful collaboration, we proposed an additional research agenda for exploring practices related to privacy requirements. This part of the research failed, not because of a general reluctance to collaborate with us (as the outcomes of the other studies we had conducted there attest), but rather because of the low interest and buy-in of employees and management in the facet of information privacy. In other words, a low level of *organizational privacy climate* hindered the collaboration on a privacy-related research study, despite the general strong tendency of stakeholders to be involved and to collaborate with the researchers. Following the execution of the research roadmap proposed in this paper, future research can further explore organizational climate in the context of IAC, not merely as a single facet climate but rather in its multiple-facet view. Accordingly, once the ORCC has been measured and addressed, topic-specific organizational climate would need to be considered. If this facet is already covered by the literature of organizational climate (e.g., safety, quality, service), then researchers would be able to mobilize existing measures. Should climate measures for this facet not exist, researchers would need to follow a general procedure of developing new organizational climate measures as a precondition, in order to allow them to measure, and when relevant manage, this facet as well.

The interplay between multiple organizational climates, however, is relevant for understanding also the single facet of research collaboration. The emergence of ORCC is affected by other facets possibly interacting with it. This effect stems from organizational climates emphasizing goals that may compete with each other, for example employees' productivity and safety, with the latter having at times a negative effect on the former [45]. Multiple climate interplay is also relevant here; ORCC may well be perceived as competing with

[4] While many different publications can be cited in the contexts listed in this paragraph, for the sake of brevity we rely here on the SLR of Garousi et al. [19] and their conclusions based on the references therein.

productivity in general, by competing for the organizations' resources, as many examples in Section 4 indicate, and could possibly even compete with the climate of the very topic on which the research is focused. For example, employees may expect easy solutions in the context of this topic, which they find highly important, only to be disappointed that, following their efforts in participating in the study, they do not receive immediate consultancy (see, e.g., [62]), but rather more long-term and abstract results, or solutions to new or emerging problems in that domain (see, e.g., [39]).

The research outline proposed in this vision paper is expected to result in both theoretical and practical contributions. The existing research on IAC in SE is currently rather limited, with only a small part thereof providing rigorous empirical evidence [19]. Moreover, IAC and the challenges it presents to SE researchers are yet to be theoretically grounded. The research vision and roadmap presented in this paper are based on recruiting a theory from the domain of organizational sciences, the relevance of which has been demonstrated in this paper, and leveraging this theory for guiding a systematic research toward facilitating an in-depth understanding of IAC challenges, and the development of potential strategies for overcoming them.

From a practical point of view, the research outline proposes developing practical means for academic researchers engaging in IAC, as well as for their industrial partners who are interested in the contributions of academic research to practice. Equipped with the outcomes of the research program, namely, ORCC measures and guidelines for interventions, researchers and managers will be able to facilitate successful collaborations by identifying and evaluating the risks of the planned collaboration, as well as to mitigate these risks. In other words, this will enable increasing the ORCC to a level that encourages employees to collaborate with the researchers and be involved in the empirical studies. Moreover, an understanding of the extent of the challenges would enable an evaluation of the resources required to achieve successful collaboration *ex ante*, enabling the participating parties to take an informed decision as to the expedience of pursuing the planned collaboration.

Practical contributions of academic research can be achieved via knowledge transfer from academia to industry, especially in the context of theory generalization, which is often formed as a *lab to field* knowledge transfer [86]. However, in the case of organizational climate theory, and specifically in our case of developing an organizational research collaboration climate, forming the theory in the lab is not an option. Since the very nature of organizational climate is rooted in the organizational context and settings, only field studies are valid. We therefore propose to form a collaboration with industry that is based on arrangements to pursue research objectives together [26], in which academic researchers develop climate measures and interventions with the full participation of the industrial partner. Multiple case studies of this form and their outcomes will guide the generalization of the research results, thus further enhancing both the practical and the theoretical contributions.

7. Conclusion

This paper proposed a vision and a respective research roadmap toward improving IAC in the field of SE, based on the organizational climate theory. Organizational climate and relevant measures have been proven to predict actual behaviors and their outcomes in different contexts. For example, measures of safety climate can predict the compliance of employees to safety regulations and, in the long run, accident frequency.

An analysis of existing evidence reported in the literature on IAC in the field of SE, through the lens of organizational climate theory, resulted in emergent categories of elicited challenges that can be related to the two basic components that determine the emergence of organizational climate: management commitment and communication (see Section 4). This analysis lays the foundation for our vision that organizational climate may serve as an effective means for addressing the discussed challenges hindering stakeholder involvement in empirical studies.

We propose that developing the concept and measures of organizational climate for the facet of research collaboration, as proposed in Section 5, would allow (a) prediction of the extent of collaboration of management and employees with the research team and specifically their expected involvement in the empirical study; (b) identification of risks challenging this collaboration; and (c) mitigation of the identified risks, using organizational climate interventions, thereby contributing to the research success. Moreover, using organizational climate measures for specific facets would allow one to choose the topics that are better aligned with the priority of the industrial partner organization, in which the empirical research takes place, thus increasing the relevance of the research to practice (see Section 6).

The execution of the proposed research roadmap would include the development of organizational research collaboration climate measures and interventions. The paper presents initial evidence, based on the literature on IAC in SE, of the viability of developing this climate's measures and interventions (see Section 5.2). These measures and interventions would provide researchers performing empirical studies in the SE industry with practical tools for making informed decisions regarding the initiation of collaborative research projects, as well as managing and improving the quality and success of these projects and their outcomes.

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References

[1] G.A. Aarons, M.G. Ehrhart, L.R. Farahnak, M. Sklar, Aligning leadership across systems and organizations to develop a strategic climate for evidence-based practice implementation, Annu. Rev. Public Health 35 (2014) 255–274.
[2] G.A. Aarons, A.C. Sawitzky, Organizational culture and climate and mental health provider attitudes toward evidence-based practice, Psychol. Serv. 3 (1) (2006) 61.
[3] J. Barling, C. Loughlin, E.K. Kelloway, Development and test of a model linking safety-specific transformational leadership and occupational safety, J. Appl. Psychol. 87 (3) (2002) 488–496.
[4] K.K. Bartels, E. Harrick, K. Martell, D. Strickland, The relationship between ethical climate and ethical problems within human resource management, J. Bus. Ethics 17 (7) (1998) 799–804.
[5] J.M. Bass, Scrum master activities: process tailoring in large enterprise projects, 2014 IEEE Nineth International Conference on Global Software Engineering (ICGSE), IEEE, 2014, pp. 6–15.
[6] F.P. Brooks Jr., The Mythical Man-Month: Essays on Software Engineering, Anniversary Edition, 2/E. Pearson Education India, 1995.
[7] R.L. Brown, H. Holmes, The use of a factor-analytic procedure for assessing the validity of an employee safety climate model, Accident Anal. Prevention 18 (6) (1986) 455–470.
[8] A. Čaušević, R. Shukla, S. Punnekkat, Industrial study on test driven development: challenges and experience, Proceedings of the First International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2013, pp. 15–20.
[9] J. Chong, R. Siino, Interruptions on software teams: a comparison of paired and solo programmers, Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work, ACM, 2006, pp. 29–38.
[10] S. Clarke, The relationship between safety climate and safety performance: a meta-analytic review, J. Occup. Health Psychol. 11 (4) (2006) 315–327.
[11] M.D. Cooper, R.A. Phillips, Exploratory analysis of the safety climate and safety behavior relationship, J. Saf. Res. 35 (5) (2004) 497–512.
[12] R. Eisenberg, P. Fasolo, V. Davis-LaMastro, Perceived organizational support and employee diligence, commitment, and innovation, J. Appl. Psychol. 75 (1) (1990) 51–59.
[13] H. Etzkowitz, The norms of entrepreneurial science: Cognitive effects of the new university–industry linkages, Res. Policy 27 (8) (1998) 823–833.
[14] S.P. Deshpande, The impact of ethical climate types on facets of job satisfaction: an empirical investigation, J. Bus. Ethics 15 (6) (1996) 655–660.
[15] O. Dieste, N. Juristo, M.D. Martínez, Software industry experiments: a systematic literature review, Proceedings of the First International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2013, pp. 2–8.
[16] K.T. Dirks, The effects of interpersonal trust on work group performance, J. Appl. Psychol. 84 (3) (1999) 445–455 1999.

[17] D.M. Fernández, S. Wagner, Case studies in industry: what we have learnt, Proceedings of the Fourth International Workshop on Conducting Empirical Studies in Industry, ACM, 2016, pp. 25–31.
[18] B. Fitzgerald, Introduction to the special series of papers on informing each other: bridging the gap between researcher and practitioners, Inf. Sci. Int. J. Emerg. Transdiscip. 6 (2003) 13–19.
[19] V. Garousi, K. Petersen, B. Ozkan, Challenges and best practices in industry-academia collaborations in software engineering: a systematic literature review, Inf. Softw. Technol. 79 (2016) 106–127.
[20] R.R. Gershon, C.D. Karkashian, J.W. Grosch, L.R. Murphy, A. Escamilla-Cejudo, P.A. Flanagan, L. Martin, Hospital safety climate and its relationship with safe work practices and workplace exposure incidents, Am. J. Infect. Control 28 (3) (2000) 211–221.
[21] T.G. Grbac, P. Runeson, Plug-in software engineering case studies, Proceedings of the Fourth International Workshop on Conducting Empirical Studies in Industry, ACM, 2016, pp. 21–24.
[22] J.W. Grosch, R.R. Gershon, L.R. Murphy, D.M. DeJoy, Safety climate dimensions associated with occupational exposure to blood-borne pathogens in nurses, Am. J. Ind. Med. 36 (s 1) (1999) 122–124.
[23] J.H. Grossman, P.P. Reid, R.P. Morgan, Contributions of academic research to industrial performance in five industry sectors, J. Technol. Transfer 26 (1) (2001) 143–152.
[24] Hadar, E. & Hadar, I. (2008). Collaborative duet of friction and traction: when the academia rubber hits the industrial road, Escaped from the Lab OOPSLA"08, October 2008, Nashville, USA.
[25] I. Hadar, T. Hasson, O. Ayalon, E. Toch, M. Birnhack, S. Sherman, A. Balissa, Privacy by designers: software developers' privacy mindset, Empirical Softw. Eng. (2017) 1–31.
[26] B.H. Hall, A.N. Link, J.T. Scott, Barriers inhibiting industry from partnering with universities: evidence from the advanced technology program, J. Technol. Transfer 26 (1) (2001) 87–98.
[27] Y. Huang, D. Zohar, M.M. Robertson, A. Garabet, J. Lee, L.A. Murphy, Development and validation of safety climate scales for lone workers using truck drivers as exemplar, Transp. Res. Part F 17 (2013), http://dx.doi.org/10.1016/j.trf.2012.08.011.
[28] F. Jaramillo, J.P. Mulki, J.S. Boles, Bringing meaning to the sales job: the effect of ethical climate and customer demandingness, J. Bus. Res. 66 (11) (2013) 2301–2307.
[29] S. Jain, M.A. Babar, J. Fernandez, Tales and lessons from the front lines of conducting empirical studies in (or with) industry, Proceedings of the First International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2013.
[30] A.P. Jones, L.R. James, Psychological climate: Dimensions and relationships of individual and aggregated work environment perceptions, Organ. Behav. Hum. Perform. 23 (2) (1979) 201–250.
[31] L.A. Isabella, Evolving interpretations as a change unfolds: how managers construe key organizational events, Acad. Manage. J. 33 (1) (1990) 7–41.
[32] M. Kajko-Mattsson, A survey of documentation practice within corrective maintenance, Empirical Softw. Eng. 10 (1) (2005) 31–55.
[33] E.A. Kapp, The influence of supervisor leadership practices and perceived group safety climate on employee safety performance, Saf. Sci. 50 (2012) 1119–1124.
[34] M.R. Karim, S.D. Al Alam, S.J. Kabeer, G. Ruhe, B. Baluta, S. Mahmud, Applying data analytics towards optimized issue management: an industrial case study, IEEE/ACM Fourth International Workshop on Conducting Empirical Studies in Industry (CESI), IEEE press, 2016, pp. 7–13.
[35] S.W. Kozlowski, B.S. Bell, Work groups and teams in organizations, Handbook of Psychology, (2003).
[36] S.W. Kozlowski, D.R. Ilgen, Enhancing the effectiveness of work groups and teams, Psychol. Sci. Public Interest 7 (3) (2006) 77–124.
[37] B.A. Kitchenham, T. Dybå, M. Jørgensen, Evidence-based software engineering, Proceedings of the Twenty-Sixth International Conference on Software Engineering (ICSE'04), 2004.
[38] M. Lang, Communicating academic research findings to IS professionals: an analysis of problems, Inf. Sci. 6 (2003) 21–29.
[39] M. Lavallée, P.N. Robillard, Planning for the unknown: lessons learned from ten months of non-participant exploratory observations in the industry, Proceedings of the Third International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2015, pp. 12–18.
[40] T.C. Lethbridge, J. Singer, A. Forward, How software engineers use documentation: the state of the practice, IEEE Softw. 20 (6) (2003) 35–39.
[41] K. Lewin, R. Lippitt, R.K. White, Patterns of aggressive behavior in experimentally created social climates, J. Soc. Psychol. 10 (1939) 271–299.
[42] G. Luria, Climate strength: how leaders form consensus, Leadership Q. 19 (1) (2008) 42–53.
[43] G. Luria, Controlling for quality: climate, leadership and quality behavior, J. Qual. Manage 15 (2008) 27–40.
[44] G. Luria, The social aspects of safety management: Trust and safety climate, Accident Anal. Prevention 42 (4) (2010) 1288–1295.
[45] G. Luria, Safety climate and supervisory-based interventions, in: S. Clarke, T. Probst, F. Guldenmund, Passmore (Eds.), Wiley-Blackwell Handbook of the Psychology of Occupational Safety & Workplace Health, Wiley-Blackwell, Oxford, UK, 2016, pp. 357–376.
[46] G. Luria, A. Boehm, T. Mazor, Conceptualizing and measuring community road-safety climate, Saf. Sci. 70 (2014) 288–294.
[47] G. Luria, D. Zohar, I. Erev, The effect of workers' visibility on effectiveness of leadership development programs: the case of supervisory based safety interventions, J. Saf. Res. 39 (2008) 273–280.
[48] S. Martínez-Fernández, H.M. Marques, Practical experiences in designing and conducting empirical studies in industry-academia collaboration, Proceedings of the Second International Workshop on Conducting Empirical Studies in Industry, ACM, 2014, pp. 15–20.
[49] N. Meyer, T. Fritz, G.C. Murphy, T. Zimmermann, Software developers' perceptions of productivity, Proceedings of the Twenty-Second ACM SIGSOFT International Symposium on Foundations of Software Engineering, ser. FSE 2014, ACM, 2014, pp. 19–29.
[50] F. Meyer-Krahmer, U. Schmoch, Science-based technologies: university-industry interactions in four fields, Res. Policy 27 (8) (1998) 835–851.
[51] A.T. Misirli, H. Erdogmus, N. Juristo, O. Dieste, Topic selection in industry experiments, Proceedings of the Second International Workshop on Conducting Empirical Studies in Industry, ACM, 2014, pp. 25–30.
[52] S. Mohamed, Safety climate in construction site environments, J. Constr. Eng. Manage. 128 (5) (2002) 375–384.
[53] D.L. Moody, Using the world wide web to connect research and professional practice: towards evidence-based practice, Inf. Sci. 6 (2003) 31–48.
[54] N. Nicholson, G. Johns, The absence culture and psychological contract—who's in control of absence? Acad. Manage. Rev. 10 (3) (1985) 397–407.
[55] L.J. Osterweil, C. Ghezzi, J. Kramer, A.L. Wolf, Determining the impact of software engineering research on practice, Computer 41 (3) (2008) 39–49.
[56] C. Parnin, S. Rugaber, Resumption strategies for interrupted programming tasks, Softw. Qual. J. 19 (1) (2011) 5–34.
[57] S. Patil, A. Kobsa, A. John, D. Seligmann, Methodological reflections on a field study of a globally distributed software project, Inf. Softw. Technol. 53 (9) (2011) 969–980.
[58] M. Perkmann, K. Walsh, The two faces of collaboration: impacts of university-industry relations on public research, Ind. Corporate Change 18 (6) (2009) 1033–1065.
[59] M. Perkmann, V. Tartari, M. McKelvey, E. Autio, A. Broström, P. D'Este, S. Krabel, Academic engagement and commercialisation: a review of the literature on university–industry relations, Res. Policy 42 (2) (2013) 423–442.
[60] L. Prechelt, F. Zieris, H. Schmeisky, Difficulty factors of obtaining access for empirical studies in industry, Proceedings of the Third International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2015, May, pp. 19–25.
[61] J.R. Rentsch, Climate and culture: Interaction and qualitative differences in organizational meanings, J. Appl. Psychol. 75 (6) (1990) 668.
[62] T.V. Ribeiro, G.H. Travassos, On the alignment of source code quality perspectives through experimentation: an industrial case, Proceedings of the Third International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2015, May, pp. 26–33.
[63] P. Rodríguez, P. Kuvaja, M. Oivo, Lessons learned on applying design science for bridging the collaboration gap between industry and academia in empirical software engineering, Proceedings of the Second International Workshop on Conducting Empirical Studies in Industry, ACM, 2014, June, pp. 9–14.
[64] S.A. Sackmann, Uncovering culture in organizations, J. Appl. Behav. Sci. 27 (3) (1991) 295–317.
[65] B. Schneider, D.E. Bowen, M.G. Ehrhart, K.M. Holcombe, The climate for service: evolution of a construct, in: N.M. Ashkanasy, C.P. Wilderom, M.F. Peterson (Eds.), Handbook of Organizational Culture and Climate, Sage, Thousand Oaks, CA, 2000, pp. 21–36.
[66] B. Schneider, J. Wheeler, J. Cox, A passion for service: using content analysis to explicate service climate themes, J. Appl. Psychol. 77 (5) (1992) 705–716.
[67] B. Schneider, M.G. Ehrhart, W.H. Macey, Organizational climate and culture, Annu. Rev. Psychol. 64 (2013) 361–388.
[68] B. Schneider, V. González-Romá, C. Ostroff, M.A. West, Organizational climate and culture: reflections on the history of the constructs in Journal Applied Psychology, J. Appl. Psychol. 102 (3) (2017) 468–482.
[69] S. Sherman, I. Hadar, Conducting a long-term case study in a software firm: an experience report, Proceedings of the First International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2013, pp. 47–50.
[70] D. Sjøberg, J. Hannay, O. Hansen, V. Kampenes, A. Karahasanovic, N. Liborg, A. Rekdal, A survey of controlled experiments in software engineering, IEEE Trans. Softw. Eng. 31 (2005) 733–753.
[71] O.L. Siu, D.R. Phillips, T.W. Leung, Safety climate and safety performance among construction workers in Hong Kong: the role of psychological strains as mediators, Accident Anal. Prevention 36 (3) (2004) 359–366.
[72] M. Söderström, T. Nordström, Regional IS knowledge networks: elaborating the theme of relevance of IS research, Inf. Sci. 6 (2003) 49–59.
[73] A. Strauss, J. Corbin, Basics of Qualitative Research, Sage, Newbury Park, 1990.
[74] A. Strauss, J. Corbin, Grounded theory methodology: an overview, in: N.K. Denzin, Y.S. Lincoln (Eds.), Handbook of Qualitative Research, Sage, Thousand Oaks, 1994, pp. 273–285.
[75] R. Stamper, K. Liu, M. Hafkamp, Y. Ades, Understanding the roles of signs and norms in organizations-a semiotic approach to information systems design, Behav. Inf. Technol. 19 (1) (2000) 15–27 2000.
[76] A. Strauss, J. Corbin, Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory, Sage Publications, Thousand Oaks, 1998.
[77] R. Suddaby, From the editors: what grounded theory is not, Acad. Manage. J. 49 (4) (2006) 633–642.
[78] O. Taubman-Ben-Ari, L. Katz-Ben-Ami, The contribution of family climate for road safety and social environment to the reported driving behavior of young drivers, Accident Anal. Prevention 47 (2012) 1–10.
[79] M.T. Tsai, N.C. Cheng, Programmer perceptions of knowledge-sharing behavior under social cognitive theory, Expert Syst. Appl. 37 (12) (2010) 8479–8485.

[80] D.N. Thompson, L.A. Hoffman, S.M. Sereika, H.L. Lorenz, G.A. Wolf, H.K. Burns, T.E. Minnier, R. Ramanujam, A relational leadership perspective on unit-level safety climate, J. Nurs. Adm. 41 (11) (2011) 479–487.
[81] U. Varonen, M. Mattila, The safety climate and its relationship to safety practices, safety of the work environment and occupational accidents in eight wood-processing companies, Accident Anal. Prevention 32 (6) (2000) 761–769.
[82] S. Vegas, O. Dieste, N. Juristo, Difficulties in running experiments in the software industry: experiences from the trenches, Proceedings of the Third International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2015, pp. 26–33.
[83] R.J. Volkema, K. Farquhar, T.J. Bergmann, Third-party sense making in interpersonal conflicts at work: a theoretical framework, Hum. Rel. 49 (11) (1996) 1437–1454.
[84] K.E. Weick, The collapse of sense making in organizations: the Mann Gulch disaster, Adm. Sci. Q. 38 (4) (1993) 628–652.
[85] K.E. Weick, K.H. Roberts, Collective mind in organizations: heedful interrelating on flight decks, Adm. Sci. Q. 38 (3) (1993) 357–381.
[86] R. Wieringa, M. Daneva, Six strategies for generalizing software engineering theories, Sci. Comput. Program. 101 (2015) 136–152.
[87] J.C. Wimbush, J.M. Shepard, Toward an understanding of ethical climate: Its relationship to ethical behavior and supervisory influence, J. Bus. Ethics 13 (8) (1994) 637–647.
[88] C. Wohlin, Empirical software engineering research with industry: Top 10 challenges, Proceedings of the First International Workshop on Conducting Empirical Studies in Industry, IEEE Press, 2013, pp. 43–46.
[89] D. Zohar, Safety climate in industrial organizations: theoretical and applied implications, J. Appl. Psychol. 65 (1) (1980) 96–102.
[90] D. Zohar, A group-level model of safety climate: testing the effect of group climate on microaccidents in manufacturing jobs, J. Appl. Psychol. 85 (4) (2000) 587.
[91] D. Zohar, G. Luria, The use of supervisory practices as leverage to improve safety behavior: a cross-level intervention model, J. Saf. Res. 34 (5) (2003) 567–577.
[92] D. Zohar, G. Luria, Climate as a Social-cognitive construction of supervisory safety practices: testing environmental and social-interaction factors, J. Appl. Psychol. 89 (2004) 322–333.
[93] D. Zohar, G. Luria, A multilevel model of safety climate: cross-level relationships between organization and group-level climates, J. Appl. Psychol. 90 (4) (2005) 616.
[94] D. Zohar, T. Polachek, Discourse-based intervention for modifying supervisory communication as leverage for safety climate and performance improvement: a randomized field study, J. Appl. Psychol. 99 (1) (2014) 113–124.