A case study of industry–academia communication in a joint software engineering research project

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

KEYWORDS
case study, collaboration, communication, industry–academia

1 INTRODUCTION

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

Despite these potential mutual benefits, researchers have identified challenges in connecting research and practice.4 The research topics and outcomes need to be relevant for industry.5,6 Research results should present practical advice to software engineering practitioners.7 The time perspectives and incentives of IA may be conflicting.8 IA have to develop a symbiotic relationship to bridge the gap between the two parties.3

Our research goal is to understand, within the context of a joint project between IA, (1) what factors can facilitate IA communication and (2) what outcomes that IA communication may contribute to. By communication, we refer to the exchange of information between people, including verbal, written and visual information, and in what context this communication takes place, for example, meetings, reports and e-mail. Further, we acknowledge that information is different from knowledge, implying that communication is a means to promote outcomes of an IA research project, not a goal in itself as could be the case for exchanging knowledge. However, we hypothesise that communication is indeed an important factor for IA projects. Further, as engineering researchers, we focus on the organisational and practical aspects of communication in the context of an IA collaboration, rather than from a purely communication science perspective.

Researchers and practitioners communicate in different contexts and for different purposes throughout an IA research project.5 Before officially starting a project, the discussions are usually focused on selecting the research topic and building the team. Once the project starts, the participants jointly define the project plan that may be more or less flexibly defined. During the operation of the project, two types of communication take place, one is related to the research work where researchers, for example, collect empirical data, and practitioners get involved in the research process. Another type of communication concerns the management and reporting of the project. Finally, the knowledge is encapsulated in scientific publications and solutions that are disseminated among researchers and practitioners. By studying the communication between researchers and practitioners, we aim to gain knowledge on how to manage communication in future IA projects.

In this study, we investigate the following research questions:

RQ1 Can we identify certain conditions, activities, relations or practices that facilitate mutual communication between researchers and practitioners?

RQ3 Given IA communication, as observed in RQ1, what outcomes for practitioners and researchers can be identified that are promoted by this IA communication?

The relation between communication and outcomes is complex, probably bidirectional, and includes many confounding factors embedded in the context. To enable us to study this complex phenomenon, we chose to conduct a case study of an IA research project to answer these questions. Case study methodology allowed us to perform “an empirical enquiry that draws on multiple sources of evidence to investigate one instance … of a contemporary software engineering phenomenon [i.e. IA communication] within it’s real-life context...when the boundary between phenomenon and context cannot be clearly specified.”10

We explored the characteristics and outcomes of the communication within our case project and validated our findings through a survey.

As our case, we studied a 3-year project within a 10-year research programme including collaboration between two Swedish universities and local branches of three industrial corporations with international outreach. Our main data collection consisted of a project retrospective that was conducted using a time-line based method11 at the closing stage of the research programme. The retrospective was conducted as a focus group meeting using a timeline as a catalyst for the data collection. The timeline visualised key events within the project and was prepared before the meeting. The audio recording from the focus group meeting was transcribed, coded and thematically analysed in line with our research questions. Later, the results from the analysis were validated through a survey with a broader population. The survey was based on the communication facilitators and related project outcomes identified in the case study.

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

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

2 | BACKGROUND AND RELATED WORK

In this section, we present an overview of the research related to our study. Firstly, we describe some perspectives considered by researchers when analysing IA research. Mainly, we are interested in how IA communication has been investigated. Secondly, we present research findings in software engineering related to IA collaboration and the role of communication. We observed that our view of IA communication might be
Researchers across disciplines have investigated IA research from different perspectives. One example is a review published by Salter et al,12 where the authors investigated the economic impact of public-funded research. The authors identified six types of contribution to economic growth related to the extension of useful knowledge, training of graduates, new scientific methods, networks and social interaction, increased scientific and technological problem solving, and new companies. Good et al. conducted a literature review from an organisational perspective of technology transfer ecosystems,13 that is, university-affiliated organisations that are involved in technology transfer activities. Specifically, the authors analysed technology transfer offices, science parks, incubators and university venue funds. The authors concluded that those structures have been studied in isolation and highlighted the need for a holistic approach. In another review, published by Perkmann and Walsh, the topic is the interaction channels between IA and the contribution to open innovation.2 In this review, IA research projects, like the one in our case study, are identified as one of the connections between IA, namely, research partnerships. Other identified connections are research services, commercialisation of intellectual property rights and people exchange. Perkmann and Walsh also found that IA research has mainly been focused on effects and less on how IA research is performed, which is what our study investigates for the aspect of communication.

Among the research about how IA work together, communication has been identified as an essential factor. Ankrah and Omar3 conducted a systematic review of 109 papers on IA collaboration across different research disciplines. They present a model to represent IA projects that covers motivations to collaborate, how the collaboration is formed and operated, the factors that enhance and inhibit the joint work, and the outcomes. In their model, communication is mentioned twice: first is as an activity throughout the joint project. Participants communicate formally or informally by voice, email, video calls, etc., and by publishing written material such as reports, booklets, newsletters, bulletins, and research papers. Second is as a factor that facilitates or inhibits the organisational management and, therefore, the joint work. Both these aspects of communication are included in our study.

Similarly, from a source of 103 papers about IA collaborations, Rybnicek and Königsgruber14 recognise the importance of communication as a factor that influences the relationship. They started their analysis based on the facilitating factors for IA collaboration identified by Ankrah and Omar3 and identified the following facilitating factors of communication.

Frequent communication is essential for developing a shared understanding of cultural differences, backgrounds and interests that may affect communication.15 Personal contacts and relationships are vital for developing work networks. These contacts are important both on the management and operational level. Companies often select partners based on their expertise and the research reputation of the institution.17 Adequate communication channels and regular face-to-face contact have a positive influence on the relationship.18 The use of common languages and mutual understanding also affect IA communication because researchers and practitioners may use different terminologies.19,20 Each partner needs to be aware of the other partner’s terminology. Cultural differences, for example, the way of working, may hinder IA research.21 Consequently, distances between the partners need to be identified and addressed early on in joint projects.21 Although some of the factors described above coincide with our findings, we identified some additional factors that may foster IA communication.

In software engineering, Garousi et al4 conducted a systematic literature review on IA collaborations, with a final set of 33 primary studies. The authors identified challenges and best practices in IA collaboration. They adopted the model proposed by Ankrah and Omar2 to represent the formation and operation of IA projects. Challenges related to communication were identified in all project phases. Some of the challenges related to communication included gaps in time horizon, areas of interest and responsibilities; difficulties at handling multiple collaborators; lack of standard terminologies; and low pre-existent networks before the projects. Following, we briefly mention some examples of best practices in line with the results of our study. Negotiate and elicit research topics with practitioners before conducting industrial experiments are examples of a best practice that may increase the trust between the participants and contribute to select industry-relevant problems.22 Another example is to have a local champion, that is, an engaged practitioner. This brings benefits to the joint project including initiating studies faster, access to data and contact with business units and stakeholders.23 To attract top management support is a best practice that balances the joint project’s research objectives and brings value to each participant.24 Another best practice is to conduct weekly meetings that may enable practitioners to more quickly test and give feedback on new ideas.25 Finally, because innovation and impact on practice take time, establishing long-term relationships is a good practice. High-quality and relevant research results tend to be supported by long-term research, rather than being the result of a short-term research project.26 An interesting observation from this study is that among the 33 papers included, 17 were by Scandinavian authors (14 by Swedish researchers). For software engineering, this factor may indicate Scandinavian countries’ willingness to develop IA research and conduct research on this topic in order to further improve it.

In a follow-up study of IA projects, Garousi et al7 surveyed 64 respondents around the world and identified which of the challenges and patterns identified in their previous study impacted the projects described by the respondents (101 projects). The authors found a high impact of challenges related to mismatches between IA, human and organisational challenges and lack or drop of interest/commitment, and less impact of communication-related challenges. Notice that for communication challenges, the authors limited their inquiry to communication channels used during the execution of the project, for example, problems with Skype or dealing with several partners. Our view of IA communication goes beyond communication channels and communication only during the execution of specific projects. We consider each researcher-practitioner
interaction a communication instance regardless of whether it happens when defining a research topic, as part of a research study, or when diffusing research results.

Researchers have investigated and proposed several models related to IA research in software engineering. Sandberg et al.27 presented a relational model that includes 10 principles for managing IA collaborations. The model is based on research on collaborative practices.28 Marijan and Gotlieb29 presented the Certus model to reflect IA knowledge co-creation. The model relies on the idea that research needs to be performed jointly by researchers and practitioners, and that this requires continuous dialogue and alignment between the participants. Similarly, Mikkonen et al.30 published a model describing continuous and collaborative technology development. Their model supports the idea that innovation is not developed in academia and transferred to industry. Instead, it is joint research between IA that leads to innovation. The first two models were derived from research programmes similar to the one in our case study, one in Sweden and one in Norway, and the third from a national research programme in Finland. Although these models do not explicitly model IA communication, they model IA research, which we believe relies on and creates IA communication.

Wohlin et al.31 surveyed IA representatives in Sweden and Australia about success factors for IA collaboration in software engineering. Having support from top management and a champion (contact person) on the industrial site was considered the top factor for success, by both IA respondents. Communication factors were not ranked explicitly (except for “regular meetings”), but they are inherent in several of the involved factors.

In summary, previous research identifies communication as one important factor in IA projects. However, there are very few studies explicitly investigating the role of IA communication.

3 | RESEARCH METHOD

The research was conducted in two main phases with a total of eight steps, as visualised in Figure 1.

In the first phase, we performed a case study of an IA research project. In the second phase, we conducted a survey to validate the findings from this case study. The survey was conducted with a broader set of participants than those included in the case study.

3.1 | Case study

The objective of the case study was to investigate our research questions, that is, to identify factors that can facilitate IA communication and outcomes promoted by such IA communication in a joint project. As our research goal was to investigate this type of complex phenomenon, where the borderline between the phenomenon and the context is not clear, we chose to perform a case study because this which would allow us to study communication in its context.10 Case study methodology is by definition based on studying one, or a small number of instances, where

![Figure 1](image_url)
generalisation can not be derived statistically but rather analytically by comparing case characteristics and assessing the relevance of the findings for other contexts. Consequently, case study findings are not focused on quantitative outcomes but on the qualitative understanding of a complex phenomenon in its context. Studying a specific case allows us to gain in-depth insight into IA communication. Our unit of analysis is a research project, as described in Section 3.1.1.

3.1.1 | Case description

The case study was conducted within The Industrial Excellence Centre for Embedded Applications Software Engineering, EASE—a 10-year research programme performed 2008–2018 in close IA collaboration. The programme involved two academic partners and three industrial partners. The partners are all active in Southern Sweden, within a 2-h drive. The industrial partners all operate on an international market, and the two larger ones are either part of, or owned by, Japanese multinational corporations. The programme budget comprised 10.5 MSEK (≈ 1 M€ or 10 full-time equivalents) per year and was jointly funded by industry (50%), academia (33%) and a national innovation agency (Vinnova) (17%). The overall goals of the programme were threefold:

- availability of competent personnel,
- making results useful for industry, and
- research excellence.

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

The research programme included three to four projects in parallel, organised around different topics in software engineering. A board of directors, composed of representatives for the funding organisations, made the decisions on which themes to explore, and the budget for each project. The detailed scope and deliverables of the projects were defined in an agile manner, focusing on mutually agreed outcomes over comprehensive documentation. Thus, the project members jointly and continuously discussed and defined what and how research should be performed within the project. Within the programme, PhD students, postdocs and faculty were funded to a varying degree throughout the programme. Master of Science (MSc) student projects were also executed within the programme, although financed by separate sources. Decisions about the acceptance of new PhD students into the programme were taken at the programme board level, whereas at the project level, specific research activities were decided. Parts of the contributions from industrial were in kind, with company employees working in, and interfacing with the research programme.

The researchers involved in the programme were active in the fields of software engineering, software technology and computer engineering. The majority of the senior researchers were Swedish natives, as were about half of the PhD students, whereas others originated from other European and Asian countries. Industry participants were dominantly Swedish, although for two of the partner companies their corporate language was English, because these companies are international and employ international staff also in Sweden. Thus, the project internal language of the studied research programme was English, whereas the communication and management culture was dominantly Scandinavian.

The collaboration practices during the formation phase of the programme are previously published, although we herein focus on a specific project that operated during the third phase, comprising the last 3 years of the programme. The joint projects executed during the last 3 years of the research programme had the following themes:

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

For each of the projects in the programme, a reference group was set up with one or more representatives from each company involved in the specific project. The reference groups met regularly with the researchers within the project to share progress reports and discuss the next research steps. Once a year, a 2-day conference was held off-site to report progress across the programme and to discuss and plan the research in more depth. In addition to these management meetings, IA representatives met to work on developing research prototypes, for interviews and empirical observations, and for planning purposes. In total, 500 IA meetings were recorded during the 10-year duration of the programme, eight PhD theses were examined, and more than 200 scientific papers were published.

*The enumeration scheme comes from Projects C and D of Phase 2 being merged into Project E.
In our case study, we investigate one of the projects that was active during the final 3 years of the research programme (theme E above), in which the four last authors of this paper were part. This project focused on decision support in the testing process. The project group consisted of six to 13 researchers and three to five practitioners, where most of the senior researchers had been involved in a previous project within the same research programme. The high proportion of researchers is due to an increase in the number of PhD students. The wide range in number of researchers is due to that PhD students and faculty members funded by other projects, also participated in the activities of the case study project in order to benefit from the IA environment provided by the research programme. Research activities in this project included literature studies and synthesis, problem conceptualisation through interviews and observations, development of solutions and evaluation of these in industrial contexts. Studies conducted by faculty, postdocs and MSc students could be run over a couple of months, whereas PhD student projects had a longer time perspective in order to fit into the thesis work. However, specific studies within the frame of PhD student projects may have shorter timelines.

Research results from the case project include systematic literature reviews (one of which included a perspective that was particularly relevant to industry, namely, industrially evaluated regression testing methods), practical guidance to industry on specific software engineering methods, for example, test scoping, automated bug assignment, and exploratory testing, and theory to explain and improve communication within software engineering. Some articles were published in practitioner-oriented magazines, whereas most papers were published in high-ranked journals and conferences. One of the subprojects is presented by Carver and Prikladnicki as an example of a successful IA collaboration in software engineering. Regularly, researchers were invited to companies to present their results, or practitioners were invited to the universities for seminars.

3.1.2 Preparing data collection through retrospectives

The main data collection for this case study was conducted at a retrospective meeting based using evidence-based timelines that facilitated reflecting on how IA had worked together within the research programme. A retrospective method called evidence-based timeline retrospective (EBTR) was used. This method enables designing a retrospective to focus on specific areas or topics through specifying goals that are then detailed into (a) focus questions and (b) aspects to visualise on timelines based on data or evidence. Both the focus questions and the visualised aspects of project history are selected with the aim of triggering and supporting group reflections in-line with the goals defined for the retrospective. In this case, the retrospective's overall goal was defined as understanding the value of the IA partnership by exploring how joint work was performed within the research programme and what benefits had been gained both short term and long term. Because this included considering by whom and how the work had been performed in each project, the material allowed us to study the communication between industrial and academic partners in the context of a research project and connected to the outcomes and benefits of that project.

Based on the goal of the retrospective, four timelines were defined. Each timeline represented an aspect of the studied research project's history. These aspects captured

- people involved in the project,
- interaction events, for example, project meetings and workshops,
- needs and activities, for example, industrial needs and research activities, and
- outcomes such as industrial impact, research results, etc.

Prior to the retrospective meeting, the available project documentation was studied, and evidence-based timelines were constructed from available project data (evidence) thereby providing a visualisation of the project history. An extract from the timelines used in the retrospective is shown in Figure 2. For each project, one timeline per aspect was defined. The second author of this paper collected the data used to populate these timelines and produced the timelines based on a selection of this data. The data were collected from project reports, minutes of meetings and publication lists. Prior to the retrospective meeting, the project participants of the studied case project were asked to complement this data by providing information not directly available in the documentation, for example, about MSc projects.

The evidence-based timelines were validated prior to the retrospective meeting by sending them out to the participants of the studied research project together with a list of key publications. The participants were asked to prepare for the retrospective meeting by skimming the material and reflecting on the main topics researched in the project, the industrial needs, gains and impacts. In addition to providing quality assurance of the timelines, involving the participants in the preparations motivated and prepared them for active participation in the retrospective event.

One moderator per project was recruited in this preparatory stage. The moderators all had previous experience of leading retrospectives and focus group sessions but had not been actively involved in the research project that they were to moderate.
3.1.3 | Data collection through retrospectives

Half-day retrospective meetings were held for each of the three projects active in the final phase of the research programme. The retrospectives were held with project members attending a physical 2-day event using a set of four timelines visualising project history. Prior to the meeting, three of the four timelines were populated based on evidence found in project documentation, namely, people, interaction events and outcomes (see above). The fourth timeline, with needs and activities, was populated during the meeting as part of the retrospective discussions. In the retrospective meeting, the pre-prepared evidence-based timelines supported the participants in remembering past project events and thus triggered and enabled a fact-based discussion guided by the predefined focus questions.11

During the retrospective meeting, the participants were presented with the partly populated timelines printed on 2 × 1 m cloth, placed on a large table around which the participants gathered; see Figures 2 and 3. The retrospective participants worked for about 3 h, analysing and discussing the research project based on the timelines. The moderator guided the retrospective meeting using the pre-prepared focus questions (see above). At the meeting, the participants alternated between individual reflection and group discussions. During the meeting, the participants populated the timelines with more details, and when necessary, corrected or adjusted pre-printed timeline data. All project members, past and present, were invited to the retrospective meeting, and for the project reported in this paper, there were eight participants from academia and three participants from industry. One of the academics acted as the moderator and led the retrospective meeting. The moderator also ensured that both the industrial and the academic perspectives were equally voiced during the meeting, although they were imbalanced in numbers. The participants from industry had all been actively involved in the project under study, and all played an active role throughout the retrospective meeting. Among the academic participants, all had been involved in the project to varying degrees, and their active participation in the retrospective varied with
the extent of their involvement in the project. Three to four of the academic participants were active in research studies, whereas the rest were involved as supervisors and in various managerial roles, thus boosting the number of academic participants.

The main outcome of this step consists of transcriptions of the retrospective meeting. The meeting was recorded using both video and audio, and the audio files were transcribed word by word by a professional transcriber. In addition, the participants made notes on the timelines of additional events, connections, etc.

3.1.4 | Coding

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

[FIGURE 3] Discussions around the timelines (placed on the table) at the retrospective meeting with case project

[FIGURE 4] The communication model used as the basis for the coding of communication instances
In the next step, two researchers (first and second authors) coded the material according to this scheme identifying all the communication instances according to the model. By a communication instance, we refer to a segment of text in the transcription that explicitly mentions communication between two communicating parties. For each instance, we coded all the categories according to the model when possible. For example, the node “researcher” in the category “Communication Party” was used all times that in the transcription, one researcher communicated with someone else.

3.1.5 | Analysis

After coding, further analysis was conducted to identify patterns in the material based on the codes and combinations of these. For example, we analysed the frequencies of codes for occurrences of communication contexts including both industrial and academic communicating parties. We settled on describing the case project using the communication contexts and the project outcomes because these provided interesting insights. During the analysis, factors facilitating communication were identified by the researchers. These facilitators and outcomes were analysed and discussed further by the researchers and are described in Section 4.

3.1.6 | Member checking

We conducted a first validation by sending out the results in the form of an early version of Section 4 to participants of the studied case project. We asked two representatives from industry and two senior researchers that had been active in the case project, to give feedback on the results. In particular, we asked them to comment on results that agreed with their experiences; what results that did not agree with their experiences; and if possible, also what results were new or surprising to them. The feedback was collected and used to validate the list of facilitating factors and outcomes.

3.2 | Survey

We performed a survey to validate the results of our case study with a broader set of participants beyond that of the studied case project. For this reason, we constructed a survey and invited survey participants through a mailing list managed by our research group. The mailing list covers our broad IA network on software engineering and consists of practitioners from different industrial organisations in Sweden.

Because this list also contains other mailing lists, it is difficult to state the exact number of participants who were invited to participate in the survey. We estimate that the mailing list reaches at least 500 email addresses and at least 60 companies. The sample was chosen because it was seen as a natural extension of the sample we worked on within the case study.

The survey instrument consisted of questions based on the case study results. The participants were asked which of the identified facilitators and outcomes they have experienced themselves in previous IA collaborations and to note additional ones. The main questions were the following:

- Characterisation questions, mainly in which sector they work, that is, industry, public sector, research institute or academia.
- What outcomes they have experienced from IA projects (selected from the identified outcomes). They were also able to add new outcomes that were not listed (in free text form).
- What outcomes the participants thought were important in IA communication (selected from the identified outcomes).
- What facilitators do the participants believe are valid (selected from a list of the identified facilitators). They were also able to add new facilitators that were not listed (in free text form).

In total, 50 respondents completed the survey. We grouped the respondents into two groups, one group consisting of 17 researchers (13 from academia and four from research institutes) and one group consisting of 33 practitioners (two from public sector and 31 from industry). In the analysis, we explain the patterns found in their responses.

For all three survey questions (confirm the validity of facilitator, experience of outcomes and importance of outcomes), the respondents could mark any number of alternatives, from 0 to 5 for the facilitators, and from 0 to 9 for the outcomes. Because we did not ask for invalid facilitators or unimportant outcomes, we believe that the respondents only marked the alternatives that were the most valid and/or important to them.
4 | RESULTS

The results of this case study consist of findings derived through analysis of the EBTRs and validation of these findings in a survey.

4.1 | Case study findings

In the analysis, we identified factors that facilitate IA communication and project outcomes promoted by this communication, based on communication instances described in the retrospective meeting. When analysing the coded transcript of the retrospective meeting, we noticed similarities between the contexts in which the communication instances were described to have taken place. Therefore, we grouped the communication instances by their communication context. We identified three main contexts, namely, the IA environment as a whole, project-related meetings, and individual studies. In the context of the IA environment, we observe IA communication beyond that of project-related meetings and individual studies. In the context of project-related meetings, project members communicate on project-related topics through meeting physically or online. Finally, in the context of studies, we observed communication in all phases of individual research studies including MSc projects. We have identified characteristics of each context that facilitate communication between IA and that promote project outcomes. The facilitators are referred to as F1–F5; see Table 1, and the related project outcomes are referred to as O1–O9; see Table 2.

In the following subsections, the identified facilitators and outcomes are presented with respect to the communication contexts in which they have been observed. Curly brackets are used in the text to denote relations identified between factors facilitating IA communication, and subsequently promoted outcomes. For example, ‘{(F1→O1)}’ denotes a relation between F1 and O1 in that factor F1 (research relevance) facilitates IA communication and thereby promotes the project outcome O1 (new knowledge). The letter C over the arrow indicates that it is an indirect relation over communication in the IA project. In some cases, more than one factor in combination were identified, and in some cases, more than one outcome were identified, which is marked by listing a set of factors/outcomes in parentheses. A summary of the relations is shown in Figure 5.

| TABLE 1 | Overview of identified facilitators of industry and academia (IA) communication |
|---------|---------------------------------------------------------------|
| Code    | Name                          | Description                                                                 |
| F1      | Research relevance          | The degree to which the research represents real problems faced by companies  |
| F2      | Practitioner's attitude towards research | The predisposition of practitioners to participate in joint research         |
| F3      | Active practitioner involvement | The degree to which practitioners participate in joint research              |
| F4      | Frequency of communication  | Particular characteristics of meetings that define a way of conducting meetings |
| F5      | Long-term collaboration     | A formal joint research project that takes place over a longer time period, for example, beyond 2–3 years. |

| TABLE 2 | Overview of identified outcomes promoted by industry and academia (IA) communication |
|---------|---------------------------------------------------------------|
| Code    | Name                          | Description                                                                 |
| O1      | New knowledge              | New knowledge that is produced in the joint project, for example, papers, code and tools |
| O2      | Awareness                  | A sense of general informed knowledge about ongoing research and results    |
| O3      | Changes in practice        | Changes that take place in companies motivated by research results          |
| O4      | Tools and source code      | Source code or tools that are implemented in products or the value chain of companies based on research results |
| O5      | Social networks            | Social and contact networks that arise and develop within IA projects and that remain beyond the time frame of a specific project |
| O6      | New studies                | New research studies and MSc projects that emerge from an IA project        |
| O7      | Good IA collaboration      | Improvements to the ecosystem to facilitate joint work                      |
| O8      | Changes in teaching        | Changes in the content of courses at University level introduced by researchers involved in an IA project |
| O9      | New scientific venues      | New forums where researchers exchange with other researchers, sprung out of IA projects |
4.1.1 | IA environment

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

The long-term collaboration (F5) supported by the 10-year research programme facilitated communication between researchers and practitioners. Within the long-term horizon of the programme, the participants’ social networks (O5) were expanded (F5 → O5). The participants expressed that this long-term aspect of the context, in some cases longer than the research projects, was inductive to initiating new studies (O6), including master thesis projects and research studies (F5 → O6). Similarly, the context provided junior researchers with an environment through which they had access to and could work with industry. The participants expressed that the continuous way of working and delivering value to the industrial partners motivated them to participate and thus led to improved IA collaboration (O7) (F5 → O7).

The industrial partners expressed that the long-term collaboration (F5) facilitated communication with academia and yielded benefits in the form of new knowledge (O1) that was useful both in the short-term and the long-term perspective (F5 → O1). This relation concerning the long-term aspect of the collaboration was expressed by one participant from industry: “We could apply the results directly…we got long-term proof that enabled us to see that, yes, we are doing the right things.” One participant also pointed out that the long-term collaboration (F5) facilitated staying focused on the agreed long-term plans without being affected by the company’s operational priorities. Thus, the research project was shielded from short-term industrial perspectives. Overall, the long-term collaboration led to mutual learning about each other, whereby the IA communication was further facilitated.

The communication between industrial and academic partners in the IA environment led to developing a social network (O5) where personal contacts, even beyond organisational affiliations, were established and kept active. During the project, some of these industrial discussion partners became actively involved in the research as formal company contacts.

Both researchers and practitioners expressed that the informal environment around the project was very positive and facilitated IA communication, which in turn generated additional IA research. Even further, the participants described that through participating in the project, they strengthened their ability to communicate with IA and that this, in turn, promoted the identification of novel ideas for further new studies (O6) and joint projects. In summary, communication in the social environment within the long-term research partnership stimulated knowledge exchange that promoted further and improved IA collaboration (O7).

Through our case study, we observed two outcomes on the academic side that were promoted through the communication with industry, one regarding teaching and one related to scientific forums. Several academic participants described that their involvement in the case project and communication with industrial partners led to changes in teaching (O8), in particular within the courses for which they were responsible. The awareness of industrial needs and the new knowledge gained through IA communication in the project thus promoted improvements to university
4.1.2 | Project-related meetings

On the basis of our empirical data, we have identified two main types of project-related meetings where IA partners communicated about research and industrial needs at a general level (as opposed to meetings related to specific research studies, see next section). These two types of meetings were either of a creative nature or related to the project organisation. The creative meetings observed in our material took place during the formation phase of the project, when senior researchers met with industrial contacts. The communication at these meetings promoted good IA collaboration (O7) in jointly defining the research direction for the project. Through brainstorming sessions involving project members from both IA, the main areas of interest were identified. As stated by one of the senior researchers involved in the management of the project, these jointly agreed areas ‘formed a frame for what was actually done’. By involving practitioners (F3) also in this formation phase, and by basing the scope on industrial needs, thus ensuring research relevance (F1) further facilitated IA communication in the project. There were multiple meetings with various companies during the formation phase. For some of these meetings, the relevance of the research and the involvement of practitioners facilitated IA communication that led to initiating joint MSc projects (O6) \((F1,F3) \rightarrow (O6)\).

The most common type of project-related meetings was project meetings. For our case project, such meetings were held regularly every 6–8 weeks with all the involved researchers and the industrial contact persons. Most of the times participants were present in person at these meetings, with the exception of researchers from one of the university sites that occasionally attended via Skype. At these project meetings, status and intermediate research results were presented and discussed, and the industrial partners shared new or changed needs from their perspective. The communication at these meetings played an essential role in promoting good IA collaboration (O7) in jointly detailing and agreeing to the research direction, and in initiating new research studies (O6). The frequency and style (F4) of these meetings and the active involvement of practitioners (F3) created a positive communication climate where ideas, needs and intermediate results were shared and discussed. For example, early on in the project, the industrial contacts expressed a preference for focusing on decision making specifically for testing when “the companies said, we want to look at testing”. This was agreed as the direction in which the research then proceeded, thereby strengthening the relevance of the research (F1) for the industrial partners. This relevance was further stimulated when “the specific [industrial] needs became studies” and thus the IA communication led to jointly defining new studies (O6) \((F1,F3,F4) \rightarrow (O6)\). An example of this is a systematic literature study that was initiated when industrial partners expressed a need to understand the state of the art regarding test case selection and prioritisation.33

Due to the industrial interest in this topic, one of the company contacts were actively involved in reviewing articles in this literature review and thereby acquired new knowledge (O1) \((F1,F3,F4) \rightarrow (O1,O6)\) through participation in the research.

4.1.3 | Studies

The research project included both research studies and industrial MSc projects related to the topics covered by our case project. The research studies were initiated based on joint agreement at the project meetings (see above) and were relevant to the industrial partners, thus ensuring research relevance for these joint studies. Similarly, the MSc projects were highly relevant to industry because companies directly initiated these projects, sometimes with a researcher within the project. These MSc projects thus stimulated further IA communication in the shape of joint supervision. These industrial MSc projects applied scientific methods to design and validate solutions to industrially relevant problems for the companies.

Research studies

The research studies within our case project were performed with industrial partners through active practitioner involvement (F3) in all phases of the studies, including research design, data collection and analysis. This active involvement, in combination with the style of meetings (F4) w.r.t. regularity and open discussions facilitated frequent and regular communication between the researchers and practitioners involved in each study. This factor related to the style of the meetings was also observed to facilitate communication at the project level meetings. Thus, the IA communication promoted that the company contacts gained new knowledge (O1) \((F3,F4) \rightarrow (O1)\) and deep insights into the research results through early access to results from the ongoing studies. This in turn enabled the practitioners to improve processes and tools within their companies. Thus, the IA communication in these meetings also promoted changes in practice (O3) \((F3,F4) \rightarrow (O1,O3)\). For example, two of the participating
companies implemented changes to their test strategies based on results obtained and communicated within the project. One company representative expressed that “when I saw some benefits, I implemented that”. Thus, the fact that the research was relevant (F1) to the industrial partners facilitated the IA communication and led to changes in practice (O3) \( f_{1\rightarrow 3} \).

Most of the research studies within our case project were performed as case studies and included activities at the companies such as data collection and research seminars. Some of the data collection methods that were used had the added benefit of disseminating new knowledge (O1) directly to the participating practitioners. In particular, this was the case for focus groups and interactive posters where the informants were presented with research ideas and topics, and asked to reflect and give their views on these either at a meeting or individually by marking their viewpoints on a publicly available poster. This approach created a win–win situation, where active practitioner involvement (F3) in the data collection facilitated IA communication which then led to the practitioners gaining insights in the shape of new knowledge (O1) \( f_{3\rightarrow 1} \). For example, a set of focus groups were held around the topic of exploratory testing where different templates for expressing exploratory test cases were presented to the participants who then got to try them out.\(^{36}\) These focus groups and the IA communication that took place there lead to changes in practice (O3) for the participating test team who ‘modified [their test practices] and have seen the direct impact’. This team also spread their new knowledge to ‘related teams within neighbouring areas’ within the company. Similarly, within a case study of ten teams, the team members were asked to assess the ease of working with other teams through voting by noting their viewpoints on posters, so called interactive posters. This approach of active practitioner involvement (F3) in the data collection facilitated IA communication and promoted an increased awareness (O2) \( f_{3\rightarrow 2} \) of the research topic (in this example, communication gaps) and an interest in the ongoing research among company employees. This involvement also enabled the researchers to spread new knowledge (O1) \( f_{3\rightarrow 1} \) of the underlying theoretical model to the entire studied department consisting of around 200 people. In this case, the company contact described that the use of interactive posters had promoted a new awareness (O2) and insight within the organisation regarding potential causes of communication gaps that helped people to be more tolerant of each other and being proactive in how they communicate with “difficult” teams.

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

Industrial MSc projects

The industrial MSc projects provided a context where communication promoted establishing personal contacts and social networks (O5) between practitioners and researchers. For example, one of the case project’s company representatives first became acquainted with one of the researchers when they co-supervised an MSc project at the company, and this then led to participating in the case project. The practitioner’s previous experience of working with the researcher positively influenced the practitioner’s attitude (F2), which further facilitated the practitioner’s communication with researchers and improved the IA collaboration (O7) \( f_{2\rightarrow 7} \). Therefore, the practitioner was more aware (O2) \( f_{2\rightarrow 2} \) of ongoing research and available to participate in new studies (O6) \( f_{2\rightarrow 6,6,7} \). The research relevance (F1) and the practitioner involvement (F3) in the project played an important role for the scope and impact of the MSc projects. Given that topics of the MSc projects were of interest to the researchers who actively participated in the project, researchers and practitioners could define the scope of these MSc projects jointly in order to become more relevant and useful to the companies and to the researchers. Furthermore, through communication of MSc projects within the IA project, similar and overlapping interests were identified in other areas of the company, which led to broadening the outreach of the results from the MSc projects.

Continuous communication between researchers and practitioners involved in industrially relevant research, provided a direct impact on practice within the participating companies. Industrial MSc projects often provided direct value in the shape of tools and source code (O4), and this relevance facilitated the adoption of these results within the companies. For example, one MSc project resulted in a tool for automatically prioritising issues in the company’s issue management system. This tool was used as is in the company’s software development organisation and thereby saved time and effort in issue prioritisation. Another example is an MSc project that implemented an automatic checker for architectural rules that removes the need for manual reviews and thereby contributes to increasing the quality of the code. This tool was integrated into the company’s development tool-chain and, thus enabled a change in practice (O3). We see in our case study that the research relevance (F1) and high practitioner involvement (F3) developed a favourable environment that stimulated communication and contributed to concrete gains and values including industrially-relevant new tools and source code (O4) and changes in practice (O3) \( f_{1,3\rightarrow 3} \).

4.2 Results from the survey

To validate the results from the case study, we conducted a survey within our collaboration network and thus with a broader sample of participants than for the case study. Note that due to the limited survey format, we could only validate the facilitators and outcomes, not the complete relational graph emerging from the rich qualitative data collected in the retrospective meeting.
The results of the survey with respect to facilitators are shown in Figure 6. The figure indicates how many researchers and practitioners agreed with the marked item as a facilitator in the IA communication for each facilitator. In the survey, all the identified facilitators were confirmed by at least half of the respondents. On average, the researcher respondents marked 3.35 facilitators and the practitioners 3.14 facilitators. As discussed in Section 3.2, we do not interpret un-marked facilitators as generally invalid, but rather as being less valid to the respondents. On the other hand, the fact that many of the respondents confirm a certain facilitator is interpreted as an indicator that this factor is a valid facilitator also for a broader sample of IA project beyond the studied case.

The participants in the survey mentioned some additional facilitators. Researchers mentioned frequency of meetings, experience of the ‘other side’, personal connections, and the attitude of the researcher (should be to transfer research, not collect empirical data). Sharing information with more frequency and researcher’s attitude were also mentioned by practitioners. They also mentioned the importance of an understanding of the basic and relevant needs of both sides.

The results of the survey concerning outcomes are shown in Figure 7. The bars marked "experience" show how many of the respondents, researchers and practitioners recognise the marked item as an outcome of IA projects. The bars marked ‘importance’ show how many of the respondents, researchers and practitioners, view the outcome as important to them when working in IA projects.

According to our survey participants, both researchers and practitioners, the most prevalent outcome of IA research is new knowledge (O1), as is shown by the responses both based on experience and with respect to the importance of the outcome. This aligns well with the case study findings, where four out of five facilitators promote new knowledge \(\{F_1, F_3, F_5\} \rightarrow O_1\). Both groups had experienced awareness (O2) and good collaboration (O7) as outcomes promoted by IA communication. However, the practitioners found awareness (O2) be more important than the researchers did. In contrast, respondents of both groups responded that IA collaboration (O7) is less important.

Changes in teaching (O8) and new scientific venues (O9) are more of a concern for researchers, but interestingly enough only considered important by 10%-15% of researchers. Likely, this outcome is not considered to be among the most important outcomes, which does not mean that it is unimportant, as discussed in Section 3.2. The fact that researchers have experienced changes in practice (O3) as an outcome promoted by communication is to be expected, as the surveyed researchers are involved in IA research projects. However, the change in practice is considered important to a lower degree, and only one in four practitioners consider this to be an important outcome.

For tools and source code (O4), social networks (O5) and new studies (O6), our respondents have experienced these as outcomes of IA communication to a higher degree than they consider them to be important outcomes. This applies to both researchers and practitioners. This is particularly worth noticing regarding new studies (O6), as the cases study findings indicate that all facilitators promote this outcome \(\{(F_1 - F_5) \rightarrow O_6\}\). Still, we interpret the responses to the question of importance as a ranking rather than an absolute assessment. Thus, new studies (O6) may be important, but, for example, our respondents view new knowledge (O1) as more important.
Some additional outcomes were mentioned by the participants in the survey. The participants in the survey mentioned some other outcomes. For participants from academia, the additional outcomes may be seen as related to awareness (O2), for example, industrial trends, real-world problems, industrial challenges, vocabulary and terms used in industry. Participants from industry, mentioned additional outcomes such as access to international experience, improved company-to-company cooperation through research projects, and recruitment, for example, through contacts with students.

5 | DISCUSSION

We now discuss the results regarding the facilitators (RQ1) and outcomes (RQ2) of IA communication. For an overview of our results, see Table 1 and Table 2 and the observed indirect relations via communication in Figure 5.

5.1 | Facilitators of IA communication (RQ1)

Our study identifies five facilitators (F1–F5) that contributed to productive IA communication in the case project. These facilitators can be viewed as characteristics of the context where the communication occurs that contribute positively to the outcome of the project.

The relevance of the topics under study (F1) and the long-term horizon of the programme (F5) facilitated IA communication within the project. The involvement of industry at the management level and in the research boosted the relevance of the research.

From our perspective, the project benefited from previous joint work, due to that the people involved had already established good practices for IA communication within the long-term programme before initiating the studied project. This included the style and regularity of the meetings, the practice of ensuring research relevance of studies, and active practitioner involvement throughout each study. In the literature, the long term perspective in IA collaborations is connected to a stronger level of commitment. In our case, the long-term nature of the IA research project provided the participants with the freedom to collaborate over a longer time period consisting of several years. Within the long-term agreements, the participants had the flexibility to define studies without any additional formalities.

One major challenge when working with practitioners is the “lack or drop of interest/commitment”. We identified active involvement (F3) and the attitude on the practitioner side (F2) as a key facilitators of IA communication. We hypothesise that these two facilitators are due to two factors. Firstly, the relevance of the research performed motivates and stimulates practitioner involvement. Examples of this from our case project are the impacts on practice observed in relation to the adoption of output from research and from MSc projects. Secondly, the trust,
respect and mutual understanding of an existing project network facilitate communication between parties. In our case project, communication between industry and academic partners flowed naturally, and people knew whom to contact and how to work with their counterparts.

In our study, the frequency of communication (F4) was identified as one facilitating factor for IA communication. The frequency of communication was also identified as a facilitating factor for collaboration, for example, by Rybnicek and Königsgruber. Similarly, we found that active involvement by practitioners and practitioners’ attitude towards research are critical to ensure the relevance of research results. These results are in line with the models proposed for joint research in software engineering that require a high degree of involvement from practitioners.

Finally, we identified the style of meetings as a facilitator of IA communication and associated this to the long-term nature of the project (F5). Even if previous systematic literature reviews have not specifically identified this factor, Ankrah and Omar conclude that “meetings and networking” are important for collaboration.

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

5.2 Project outcomes (RQ2)

We identify the project outcomes promoted by IA communication for academia and industry, respectively. For the academics, working with industry can impact teaching (O8) and research (O6), and for practitioners, the impact can be seen in changes to practice (O3). For both parties, the communication promotes increased knowledge (O1). Given that researchers are often teaching university courses, the knowledge exchange with industry has an indirect effect on the students and, therefore, on future software engineers. Suppose the education of future practitioners receives the input from research conducted with the input from the industry. In that case, this enriches a critical mass of (new) professionals and industry has an indirect effect on the students and, therefore, on future software engineers. For both parties, the communication promotes increased knowledge (O1). Given that researchers are often teaching university courses, the knowledge exchange with industry has an indirect effect on the students and, therefore, on future software engineers. Suppose the education of future practitioners

An important benefit for researchers of IA projects is access (O5) to and insights into industry, which enables researchers to collect empirical data and validate research findings. Furthermore, the case project facilitated exchanges with researchers in general, both those directly involved in the project and others through personal contacts. These exchanges are valuable because they enable validating results and considering other viewpoints. Researchers and practitioners all benefited from these exchanges.

For practitioners, the outcomes of working with academia are both direct and indirect. Direct outcomes include changes in practice motivated by research findings (O3) and tools and source code originating from the research (O4) that can be used at the companies. Industry often views these contributions as the main gain and outcome of an IA project. These two outcomes were also in line with the overall goals of the EASE programme, in particular the goal of results useful for industry; see Section 3.1.1. However, the survey results indicate that these outcomes are less valued than new knowledge in general.

We have identified an additional indirect outcome of the IA communication in the shape of increased awareness of research among practitioners (O2). Our analysis indicates that this awareness, in contrast to knowledge that has a direct industrial application, may impact practitioners in several ways e.g. inspiration for new products, benchmarking with other practices, and increased confidence gained from selecting practices based on research findings. Overall, both types of benefits need to be considered when evaluating the benefits of IA research projects, because the potential gains influence industrial partners’ willingness to commit and actively participate in IA research projects. The possibility to reach these objectives is an important factor in facilitating industry participation.

We identify knowledge exchange between industry and academy (O1 and O2) as an outcome of the communication that occurs within individual studies and throughout the entire project. As is expected, new knowledge is built-in research studies, and communication contributes to achieving the goals of the studies. In addition, IA research projects can contribute to a positive cycle that leads to further studies and mutual learning. Professional relationships are cultivated through IA project activities and exchanges during meetings. Many of these relationships go beyond the project lifetime and may lead to additional future IA interactions. In general, IA communication fosters more collaboration.

In the survey, many of the outcomes received high scores, both regarding the degree to which they have been experienced, and to what extent participants think they are important. However, there are some outcomes that did not receive high scores with respect to both aspects. Outcomes related to industrial practice (O3 and O4) were considered less important than outcomes related to knowledge and awareness (O1, O2). This difference in ranking indicates that, in general, there is more interest in outcomes related to knowledge than an immediate practical impact. Another possible view is that research results rarely are directly applicable to a specific industry setting but needs to be generally understood first and then adapted to the specific setting. Outcomes related to impact on research and teaching (O6, O8, O9) were, by a majority of the respondents, not marked as important, either by researchers or practitioners. As we see, outcomes that impact research and teaching may not be
perceived by the participants as a priority or experienced to the same degree as other direct outcomes. However, these outcomes are indirect and visible in the long term.

As described in Section 4.2, the survey participants mentioned some additional outcomes. However, many of these correspond to the need for knowledge and awareness (O1, O2). Participants mentioned, for example, the need for knowledge about industrial trends and real-world problems. In the same way, participants mentioned, for example, having access to international experience and recruitment of personnel as outcomes.

5.3 Validity of contribution

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

Construct validity is about the concepts of the study, particularly IA communication and context. Our empirical data were collected from a retrospective meeting that had the goal of reflecting on the IA research project based on a timeline visualising projects events and outcomes. The objective of the retrospective was to investigate how IA had worked together within the research programme, not specifically focusing on communication in isolation. There is a risk that the retrospective did not focus enough on communication for this study. However, a large share of the timeline data was focused on communication, which is one reason why we selected to study IA communication for this case project and we found that the data was useful for studying communication due to the variety of communication instances found in the material. Furthermore, the survey helped us to mitigate this risk by confirming the results with project participants and survey respondents. Internal validity relates to the suggested relationships between data entities, in this case, facilitators and outcomes. Propositions of these relationships are based on an aggregation of assumed connections between the entities in our coding scheme. These connections were identified in the data and need to be further tested. There is a risk of researcher bias in the analysis that may affect the reliability of our results. We partly mitigated this risk by working in pairs and by systematically applying thematic coding. Our familiarity with the project is both a risk and a strength. The risk is that of confirming our prior beliefs without considering the data. This risk is partly mitigated by using a bottom-up approach in the coding (i.e., the facilitators were derived after the coding), and partly by asking other project members to read and comment on the results. This validation was performed by sending the manuscript to three practitioners and two senior researchers involved in the case project, four of which responded. Furthermore, the risk of misinterpretations is partly mitigated by the researchers being familiar with the case project, and knowing the people involved. External validity describes the generality of our results. We formulate our contribution to be applicable in any IA research project, and our findings can, thus, be tested also in other contexts. Our results are derived from observations in a single case study. The survey was an initial step towards external validity where additional people from IA confirmed the identified facilitators and outcomes. Survey participants mentioned additional factors, for example, mutual trust and understanding, style of communication, researchers attitude, and recruitment of graduating students. However, in general, the results of the survey, as described in Section 4.2, strengthen the generality of our findings. Future research may investigate these factors and further strengthen the generality of our results.

6 CONCLUSIONS

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

We collected empirical data that were analysed according to a simplified model of communication (Figure 4) describing instances of communication where each instance represents IA communication between two parties, within a context, and having explicit communication outcomes. Through analysis of such communication instances, we identified elements that facilitate communication between industrial and academic partners (RQ1) and examples of project outcomes that were promoted by IA communication (RQ2). These facilitators and outcomes, as reported in Section 4, provide empirically based insights that may be used to guide the setup of similar joint projects and thereby improve IA communication. Furthermore, the extended of IA communication, including the observed contexts of communication, facilitators and project outcomes, may inspire future research on the characteristics and relationships between these proposed constructs of IA communication, which we find much needed.
In summary, the following recommendations may facilitate IA communication in joint research projects and subsequently stimulate the project outcomes identified as being promoted by IA communication:

Ensure that research is relevant to all participants by discussing and jointly agreeing to the scope of IA research programmes, projects and studies. Practitioners will be more willing to engage in research activities, if the research topics and results are relevant and applicable to their work challenges. We noticed how addressing problems experienced by practitioners contributed to developing a favourable IA collaboration climate supported by communication that stimulated and led to changes in practice and new knowledge. Foster a positive attitude towards research by listening to the needs and interests of industry and aiming to provide value to practitioners through research. The view and attitude of practitioners towards research, researchers and research results influence their involvement in, and commitment to, research activities. We noticed that practitioners with trust in and previous positive experiences of collaborating with researchers had a positive attitude towards further such collaboration, which facilitated the communication with researchers. Promote active practitioner involvement by openly discussing plans and emerging research results and by inviting practitioners to take an active role, for example, in reviewing papers and writing articles. An active engagement of practitioners in research projects contributes to identifying and addressing industrially relevant problems in research studies. Furthermore, these engaged practitioners are critical in leading and promoting changes in practice based on research results. We noticed that the active involvement of practitioners was a critical factor that led to having discussions around industrially relevant topics with researchers. From these dialogues, new studies emerged around industrial challenges, and practitioners were made aware of research in the field. Regularly hold both formal and informal meetings with a clear focus and adapted to the specific needs, for example, of overall project synchronisation versus work meeting. IA communication and goal achievement are stimulated by a combination of formal meetings for project management, and open and informal meetings where creativity flourishes. Establish a long-term collaboration between IA through joint projects and networking events. A long-term collaboration contributes to creating social networks, identifying more research studies and the possibility to apply results in the academic and industrial contexts. In addition, the long-term aspect of a collaboration allows researchers and practitioners to gain insight into each other's spheres and to develop good practices and ways of working together.

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DATA AVAILABILITY STATEMENT
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