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Do you know your people?: Situated expertise and permeable expertise boundaries in complex project work

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ABSTRACT

In the context of complex and digitalized engineering projects, effectively orchestrating meta-knowledge that encompasses awareness of diverse expertise presents a significant challenge, as it requires crossing various boundaries. Situated expertise plays a critical role in this process, connecting individual or group-level meta-knowledge to wider expertise systems in projects. We report a case study exploring how group expertise boundaries influence situated expertise development in the oil and gas front-end project context. Through qualitative analysis, we underscore the role of permeable group expertise boundaries in fostering open situated expertise systems, allowing for meta-knowledge about individuals, groups, and digital technologies. This permeability is especially critical in innovative and non-contractual contexts. We identify four elements—strategy, structural design, interaction molding routines and roles, and digital boundary objects—that contribute to open situated expertise development. Our findings show that while digital boundary objects can mediate expertise boundaries by enabling communication and navigation of expertise in projects, the reach of situated expertise largely depends on interaction molding elements, particularly boundary-spanning roles. This study concludes by recommending that practitioners expand their meta-knowledge, rethink their strategic approaches to situating and utilizing expertise in projects, and carefully establish routines for using digital technologies to record and retrieve expertise.

1. Introduction

As knowledge intensity grows and digitalization advances, the performance, learning, and creativity in complex engineering projects increasingly rely on effectively orchestrated expertise systems (Hussein, 2020; Korotkova et al., 2024; Schou and Nesheim, 2024; Steen et al., 2018). In these systems, project members proactively develop and leverage meta-knowledge about 'who knows what' and 'who knows whom' (Mell et al., 2022), enabling them to map, connect, and update expertise essential for project work (Hansen et al., 2020; Heimstädt et al., 2023). Given the growing importance of managing interorganizational project collaboration (Martinsuo and Ahola, 2022), reliance solely on meta-knowledge within a project group may no longer be adequate. Project members may benefit from extending their meta-knowledge both digitally and non-digitally (Dibble and Gibson, 2018; Nisula et al., 2022). However, research on meta-knowledge and expertise systems remains preoccupied with knowledge processes occurring within group expertise boundaries (Austin, 2022; Dibble and Gibson, 2018; Mayo et al., 2017). More research is therefore needed on expertise boundaries (Kislov, 2018), their permeability, and their impact on the development of expertise systems crossing multiple boundaries in project contexts (Austin, 2022; Mell et al., 2022; Song et al., 2022; Sydow and Braun, 2018).

To ground our exploration of how project group expertise boundaries are perceived and how expertise systems are developed in complex project groups, we delve into *situated expertise* development at the front end of complex engineering projects. The concept of situated expertise involves actively integrating individual or group-level meta-knowledge with the broader expertise systems (Austin, 2022). This integration is achieved through proactive efforts to locate and maintain expertise

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within the organizational context, ensuring its relevance and accessibility. Austin (2000) earlier characterized situated expertise as the combination of group members' internal meta-knowledge and their external social connections. The revised definition underscores the importance of permeable group boundaries to effectively situate expertise in dynamic project contexts characterized by evolving tasks and shifting project members (cf. Austin, 2022).

Unlike in permanent groups, expertise-situating processes in temporary contexts usually occur in weakly coupled and dynamic networks (Hsu et al., 2016; Nisula et al., 2022; Sydow and Braun, 2018). Developing situated expertise systems in the project context can thus be a 'moving target,' as project members, their knowledge, and project problems are in continual flux (Barrett and Oborn, 2010; Carlile, 2002). Hence, more research is needed on how situated expertise systems are developed in temporary contexts, blurring project group expertise boundaries (Hansen et al., 2020; Hsu et al., 2016; Mohammed et al., 2021).

To understand the development of situated expertise systems crossing multiple boundaries in complex project work, this paper draws on situated expertise and boundary research (e.g., Argote et al., 2018; Bachrach et al., 2019). We place a particular focus on the role of group expertise boundaries, their permeability, and digital boundary objects. The latter concept attracts growing scholarly attention due to the potential of digital boundary objects to mediate expertise boundaries (Alin et al., 2013; Hetemi et al., 2022; Nicolini et al., 2012). Boundary objects are commonly defined as mediating artifacts with substantial interpretive flexibility that may support knowledge sharing between diverse groups (Barrett and Oborn, 2010). Effective digital boundary objects, such as 3D project tools, may enable the bridging or overcoming of boundaries between experts and groups by representing their expertise differences and reconciling them in complex knowledge tasks, such as engineering design (Alin et al., 2013; Chang et al., 2013; Hetemi et al., 2022). Nonetheless, our understanding of whether and how different elements, including digital boundary objects, impact the permeability of group expertise boundaries and the subsequent development of situated expertise systems in projects remains limited (Alin et al., 2013; Dibble and Gibson, 2018; Whyte, 2019).

In this study, we aim to advance our understanding of group expertise boundaries and the emergence of situated expertise systems in projects by empirically exploring how expertise-situating processes play out in complex project work crossing multiple boundaries. To do so, we pose the following research question: *What is the role of group expertise boundaries in the development of situated expertise systems in complex engineering projects?*

We report a qualitative case study that delves into the development of situated expertise systems in three oil and gas engineering projects in Norway, focusing on how project members experience group expertise boundaries and their role in shaping situated expertise systems. Through this study, we (1) reveal the significance of permeable group expertise boundaries in complex project work, (2) identify four key elements contributing to the development of open situated expertise systems in projects, and (3) show that although digital boundary objects mediate expertise boundaries by enabling the communication and navigation of expertise and experience, the development of situated expertise mainly relies on specific interaction practices (molding routines) and roles in temporary contexts.

The remaining part of this article is structured as follows. We begin with a review of the literature on meta-knowledge, situated expertise, group boundaries, and digital boundary objects. We then present our research approach and results, focusing on the permeability of group expertise boundaries and elements impacting situated expertise development in complex project work. Our conclusion presents the implications for both theory and practice and suggests potential avenues for future research.

2. Conceptual background

This section provides the conceptual background of our study. We first reflect on expertise and meta-knowledge to position situated expertise in the current academic debate. Then, we briefly review the literature on group boundaries and expertise systems development, underpinning the role of digital boundary objects.

2.1. Expertise and meta-knowledge in project work

At its essence, the concept of situated expertise (Austin, 2022) can be viewed as a form of meta-knowledge combined with action based on that knowledge. Meta-knowledge involves recognizing each project member's unique expertise and social connections, creating awareness of '*who knows what*' and '*who knows whom*' within the project group (Mell et al., 2022). Continuously developing and maintaining accurate meta-knowledge about fellow project group members' expertise (e.g., 'who designs a flexible pipeline' or 'who knows drilling experts') empowers group members to effectively map out and utilize expertise scattered within the group (Lewis, 2004). This detailed expertise mapping facilitates the use of group members and external networks as cognitive extensions (Jain, 2020), providing access to a broader pool of expertise adaptable to changing project needs (He et al., 2007).

Meta-knowledge is especially vital in handling complex design tasks in engineering projects. In this knowledge-intensive context, group members may leverage a wider array of subject-specific expertise (e.g., how to design a wellhead connector) beyond the capacities of single project members (Ahlfänger et al., 2022; Engelbrecht et al., 2019; Korotkova et al., 2024; Mayo et al., 2017; Mohammed et al., 2021). This broadened access to others' expertise fosters improved performance, learning, and creativity within project groups (Austin, 2003).

Scholars have primarily explored meta-knowledge within permanent group boundaries (Mortensen and Haas, 2018; Wegner, 1987). In the contemporary project context, project performance, however, often hinges on collaboration with experts beyond project group boundaries. This includes experts scattered across internal departments and external stakeholders, such as customers and vendors (Sydow and Braun, 2018). Recent developments in project studies, particularly given the rise of research on multi-organizational projects and project networks (Manning, 2017; Martinsuo and Ahola, 2022), also underline the necessity of shifting our focus towards understanding and utilizing meta-knowledge that extends beyond the boundaries of individual project groups. Therefore, we draw on literature related to group (expertise) boundaries (e.g., Dibble and Gibson, 2018), which we will briefly review in the following sections. This sets the groundwork for our main focus: the concept of situated expertise.

2.2. Crossing group expertise boundaries in complex project work

Group boundaries are often viewed as structures primarily serving to separate the group from external actors, filtering and managing knowledge flow and social interactions between them (Choi, 2002; Leonardi et al., 2019). Groups have also often been seen as bounded social systems with formally defined, clear, and relatively closed boundaries (Hackman, 2002; Wimmer et al., 2019). However, this conventional notion of clear group boundaries has been increasingly questioned, with scholars contending that a portion of collective work unfolds beyond these boundaries (Dibble and Gibson, 2012; Mortensen, 2014). This shift in perspective, necessitating a new approach to study groups and boundaries, has sparked research on the circumstances and motivations driving individuals and groups to engage in boundary-spanning behaviors facilitating knowledge sharing across boundaries (Ancona and Caldwell, 1992; Kislov, 2018; Levina and Vaast, 2005).

Scholars underscore that the impact of crossing group boundaries on project group performance is contingent on the degree to which the group boundaries are permeable or closed to flows of knowledge, information, resources, and people (Dibble and Gibson, 2012, 2018; Mortensen, 2014; Workman, 2005). However, recent research on boundary permeability often lacks clarity about what exactly is moving across boundaries (Kislov, 2018; Mell et al., 2022; Mortensen and Haas, 2018). In our study exploring the development of expertise systems in complex project work, we focus on *group expertise boundary permeability*, which we define as the ease with which project group members can identify and access expertise beyond the boundaries surrounding their immediate or core project group. Hence, we look at group expertise boundaries demarcating the flow of expertise rather than resources, people, or work (Dibble and Gibson, 2018) across group boundaries and at the ease with which expertise cross group boundaries. The latter aspect provides insights into the experiences of project group members situating expertise and elements that are under control of both these members and managers orchestrating expertise systems (Mell et al., 2022).

Recognizing the essence of permeable group expertise boundaries and the fluid and dynamic nature of project work (Dibble and Gibson, 2018), our research employs the concept of *situated expertise* (Austin, 2000, 2022). This concept illuminates meta-knowledge embeddedness in the broader (inter)organizational context, extending the traditional focus on meta-knowledge within group expertise boundaries. Situating expertise involves the integration of expertise across group boundaries, encompassing the acquisition and collective utilization of external expertise by the recipient project group (Mell et al., 2022). By integrating external expertise, project group members disseminate, translate, and recombine external insights (Bechky, 2003; Carlile, 2004), making them an integral part of the project group's work and decision-making processes (Mell et al., 2022). Such integration of external expertise enriches the recipient project group's collective knowledge base, which might become a valuable asset for future projects, reducing the need for external searches, fostering a group's internal capabilities (Bresman, 2010; Mell et al., 2022), and improving group performance (cf. Balkundi and Harrison, 2006). Cultivating an environment that encourages the permeability of project group expertise boundaries for situated expertise is thus crucial. Such an environment not only enhances project outcomes through more effective knowledge utilization but also contributes to the long-term development of the group's expertise and performance capabilities.

Group expertise boundaries, their permeability, and situated expertise have, however, received relatively limited scholarly attention thus far (Austin, 2022; Kislov, 2018). Therefore, there is a growing call among scholars for future research to develop these concepts further, focusing on analyzing the antecedents of group expertise boundary permeability and its role in shaping expertise systems (Wimmer et al., 2019). Furthermore, Dibble and Gibson (2018) highlight the necessity of shifting the predominant focus from the drawbacks of permeable boundaries (Hackman, 2002) to the positive aspects of crossing group boundaries.

2.3. Development of situated expertise systems in complex projects

Exploring the role and potential benefits of crossing group expertise boundaries in complex project work requires a thorough examination of situated expertise development, namely how and why individuals develop extra-group meta-knowledge in a broad project context (Austin, 2022; Bachrach et al., 2019; Dibble and Gibson, 2018). This requires attention to different elements impacting the permeability or impermeability of group expertise boundaries (Workman, 2005).

Earlier studies have provided some insights into how permanent groups develop expertise systems. Peltokorpi (2014) identified three mechanisms of shaping expertise systems at the organizational level: organizational design, human resource management (HRM) practices (e.g., mentoring, reward systems), and relational interactions. Scholars also hypothesized that expertise is more likely to cross group boundaries when boundary spanners—individuals responsible for contacting people and transferring knowledge across group boundaries (Friedman and Podolny, 1992)—contribute specialized and complementary expertise and are strongly embedded in their groups (Olabisi and Lewis, 2018). Embedded boundary spanners are believed to be better positioned to maintain accurate meta-knowledge, ensuring knowledge dissemination to the relevant group experts (Leonardi, 2017; Mell et al., 2022; Olabisi and Lewis, 2018). For instance, if the marketing group passes customer feedback to the engineering department through an embedded boundary spanner, there is a higher likelihood that the engineering group will incorporate information.

Recent studies have amplified their focus on the role of digital boundary objects as potential tools for codifying and coordinating knowledge and expertise, blurring conventional group expertise boundaries (e.g., Azzouz and Papadonikolaki, 2020; Engelbrecht et al., 2019; Leonardi et al., 2019; Papadonikolaki et al., 2019). ***Digital boundary objects*** are mediating artifacts that can bridge or overcome knowledge boundaries between different collaborating experts and groups with domain-specific expertise (Alin et al., 2013; Barrett and Oborn, 2010; Nicolini et al., 2012). Digital boundary objects (e.g., archives, search engines), as external memory vehicles, might help individuals to navigate and 'outsource' memory work by offering codified knowledge about the expertise and experiences of individuals from different domains (Boland et al., 2007). For instance, Leonardi (2015) found that using enterprise social networks for 6 months enhanced 'who knows what' and 'who knows whom' knowledge by 31 and 88 percent, respectively. However, studies underscore that the usefulness of digital boundary objects for collaboration across boundaries may vary (Carlile, 2002; Korotkova et al., 2023; Leonardi et al., 2019), and their ability to facilitate situated expertise development depends on individuals' willingness to share expertise. Although Goffman (1959) posited that individuals should be motivated to formally share their expertise due to the possibility of favorable self-representation, empirical studies report that they often fail to share knowledge digitally (Leonardi, 2017). Furthermore, effectively leveraging digital boundary objects to situate expertise in projects may necessitate the involvement of embedded, skillful, and competent boundary spanners tasked to translate the meaning of these objects into local contexts (Azzouz and Papadonikolaki, 2020).

Numerous studies have explored the role of digital technologies in project context (Azzouz and Papadonikolaki, 2020; Oraee et al., 2019; Papadonikolaki et al., 2019) and the use of digital boundary objects for communication across boundaries (Chang et al., 2013; Hetemi et al., 2022; Leonardi et al., 2019). Yet, research on the use of digital boundary objects, among other elements, for the development of situated expertise systems in projects remains limited (Alin et al., 2013; Engelbrecht et al., 2019; Leonardi, 2015). This gap is especially pronounced in project studies, where limited scrutiny of the meta-knowledge concept exists (e.g., Hansen et al., 2020; Hsu et al., 2016; Lin et al., 2015), offering minimal exploration of the expertise-situating processes in extra-group contexts.

Empirical and conceptual insights into how different elements influence situated expertise development are of utmost importance in the temporary project context. This is particularly significant because project group members often need to collaborate with actors with whom they lack a shared history of collaboration (Nisula et al., 2022; Steen et al., 2018). The ever-changing nature of project membership can also lead to a reliance on outdated meta-knowledge (Lewis et al., 2007). Despite these crucial considerations, there remains a significant gap in our understanding of the elements influencing the movement of expertise across project group boundaries (Dibble and Gibson, 2018). Scholars, therefore, emphasize the need for a systematic examination of situated expertise development (Austin, 2022; Bachrach et al., 2019; Korotkova et al., 2024) and an in-depth understanding of how different elements, including digital boundary objects, can mediate group expertise boundaries in project contexts.

Reflecting the identified gaps, our study aims to explore how project members experience group expertise boundaries and their impact on situated expertise development by identifying different elements contributing to their awareness and use of expertise.

3. Research design and methods

This study adopts an interpretive case study research design (Yin, 2018) to investigate—from the perspective of those studied (Pratt, 2009)—the role of group expertise boundaries in the development of situated expertise systems in complex engineering projects.

3.1. Case selection

We collected data on a large service provider company delivering complex subsea solutions for the oil and gas industry (anonymized as 'Alpha'). As a result of a recent merger of subsea equipment ('Alpha 1') and subsea production system ('Alpha 2') supplying companies, Alpha delivers integrated engineering solutions—from design to decommissioning—for the oil and gas value chain (see Fig. 1). At the time of the study, Alpha employed more than 20,000 employees in 41 countries, with more than 2000 in Norway.

In the supplier business, oil operators play an essential role, including their involvement in discussing, (co)designing, and selecting functional solutions (Thune et al., 2019). Therefore, we studied Alpha's knowledge collaboration with one of its customers, a medium-size oil operator company ('Beta'). Beta operates in 8 countries with 1400 employees, of which around 300 are based in Norway. Alpha and Beta have a long collaborative history, including a strategic alliance signed in 2018. Moreover, since 2019, the companies have enhanced their focus on digitalizing customer–supplier relations. By doing so, the companies sought to facilitate early, trustful customer–supplier knowledge collaboration in projects, where collaborating actors could review more cases, perform better revision control, and, thereby, accelerate the time to the first oil. Considering these trends, understanding whether and how different expertise crosses project group boundaries was critical for both companies.

3.2. Case context

In collaboration with the companies, we decided to focus on the development of cross-boundary expertise systems in the front-end phases of three ongoing projects (projects A, B, and C), where Beta was the main supplier of integrated project delivery. The front-end project phase incorporates feasibility, concept, concept select/pre-FEED (front-end engineering and design), FEED, tender, and contract award at decision gate 3 (Fig. 1).

We focused on this shaping of the project phase (Zerjav et al., 2021) due to the strategic importance of front-end decision-making in oil and gas projects. Idiosyncratic front-end project work requires designing unique solutions that fit a specific geological area. This necessitates front-end knowledge collaboration between multiple Alpha and Beta experts—several hundred project members from up to 20 departments—in drafting, designing, and selecting an economically and technically feasible solution based on evaluating 5 to 20 concepts.

Our first meeting notes revealed a firm belief among managers and engineers that digitalization has caused a rethink regarding the front-end integration of Alpha and Beta experts. At the same time, we observed that situated expertise systems were fragmented and lacking digitalization. There was also limited recognition of the value of situated expertise in the organization of front-end project work. We thus proceeded to explore the presence and value of cross-boundary expertise systems and elements, including digital technologies, affecting situated expertise development in complex project settings.

3.3. Data collection

This study comprises primary and secondary data sources collected during two consecutive stages from May 2019 to November 2021 (see Fig. 2 for details). Following inductive reasoning, the first exploratory stage of data collection started with observation and meetings, where we mapped practices and drivers of and barriers to situating expertise at the projects' front end. In the following stage, focusing on the role of digital technologies in the development of expertise systems, we observed an immense number of digital tools in both companies (1700–3500 tools in Alpha). However, no single technology emerged as the main means of expertise navigation. Therefore, we holistically explored digital objects that project members utilized to situate expertise.

Interviews served as the primary source of knowledge on situated expertise development and its digitalization, while non-participatory observation and document analysis (e.g., presentations, organizational project charts, and websites) served as useful secondary sources providing new insights on practices of situated expertise development. Following the principle of saturation, we conducted 51 semi-structured interviews with Alpha representatives and 14 with Beta representatives; of them, 62 were individual and 3 were group interviews. The interviews were conducted face-to-face and via phone, email, and video-communication platforms (e.g., MS Teams, Zoom, and Skype) and lasted from 45 to 150 min, with an average of 90 min. The interview data eventually accounted for 88.5 h of audio recordings, which were verbatim transcribed by the first author due to the specific oil and gas jargon and to perform the initial coding.

Consistent with other expertise studies (e.g., Jarvenpaa and Majchrzak, 2008), we drew on the individual level of analysis, which is cardinal for understanding how individuals experience, interpret, and infer others' expertise. To capture situated expertise development practices from different angles, the recruitment of interviewees followed a logical pattern of project collaboration with the consequent recruitment of new candidates through snowball sampling. As a result, the research sample comprised central supplier and customer actors of different genders and nationalities (mainly Norwegian, French, US, and UK nationals) with distinct job positions and work tenures (from 3 to more than 40 years). Three main groups of informants were included: (1) managerial and commercial specialists (e.g., VP product management, sales manager, learning & development manager; 10 interviews); (2) engineering leaders (e.g., director of front-end & system engineering management, project director) and engineering specialists (e.g., engineering manager, subsea engineer; 30 interviews in total); and (3) digital leaders (e.g., digital transformation director, director of innovation and development) and digital specialists (e.g., digital subsurface team

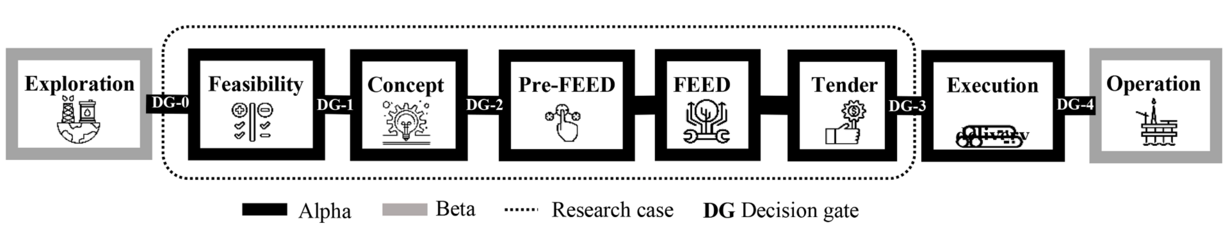

Fig. 1. Oil and gas value chain and research case.

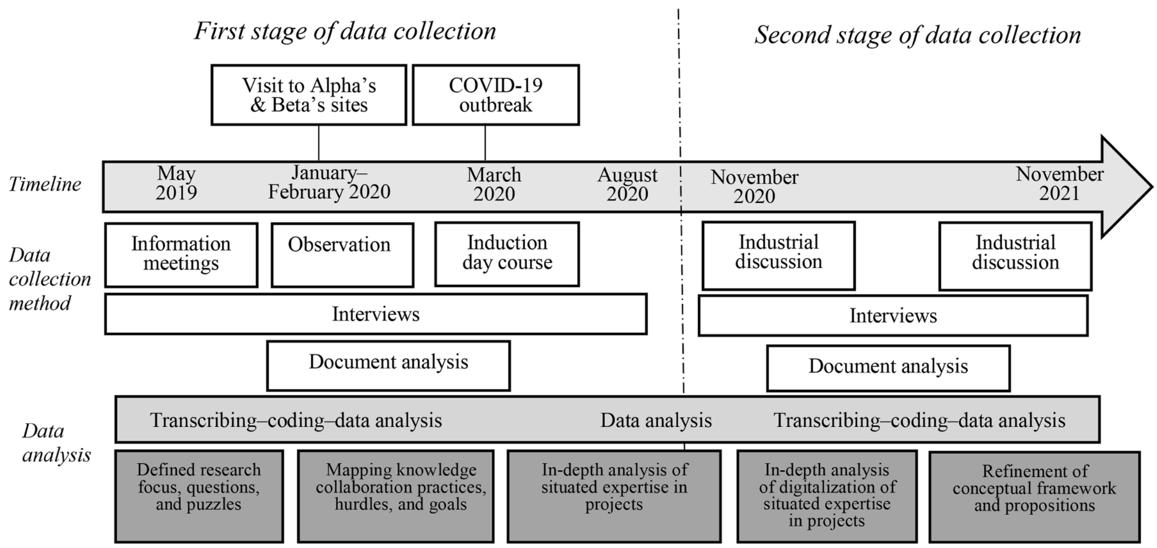

Fig. 2. Data collection overview.

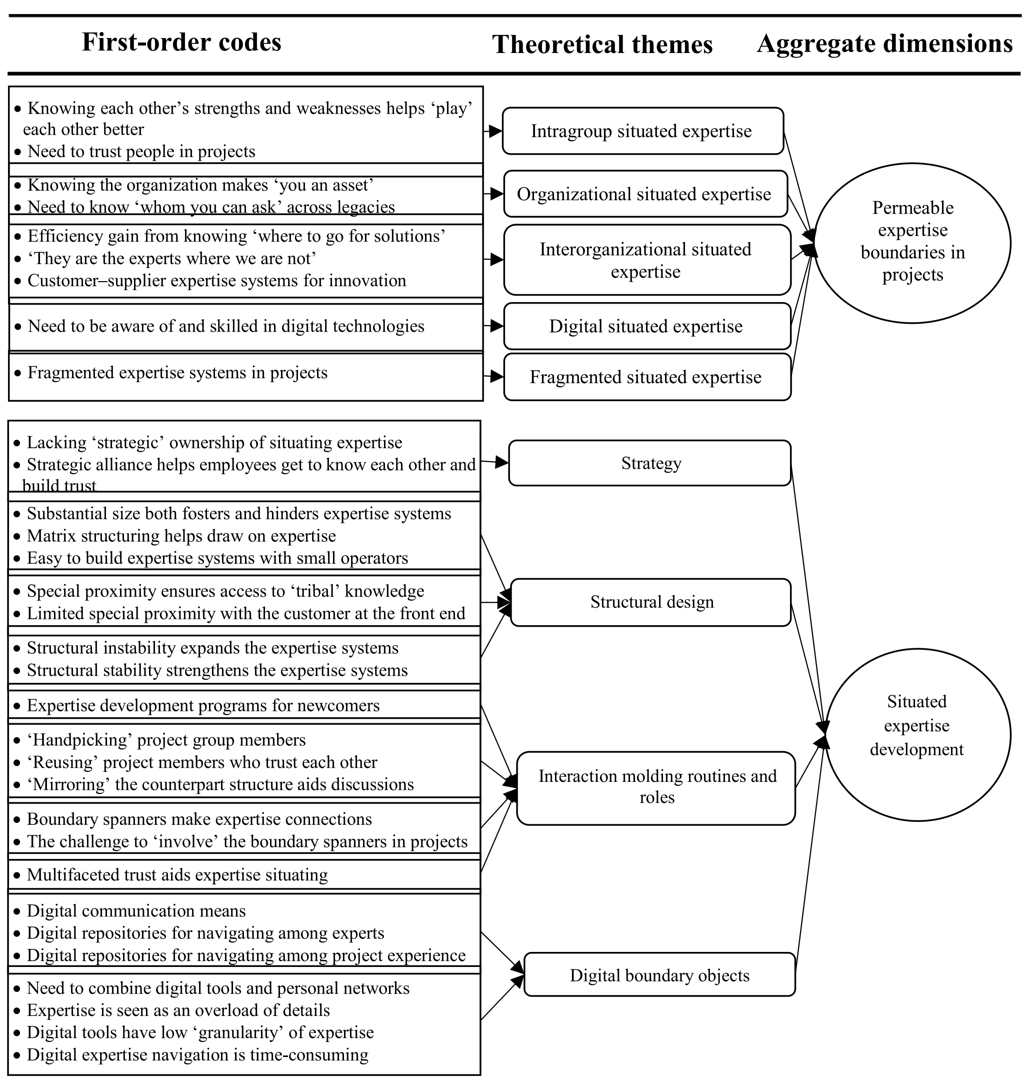

Fig. 3. Data structure.

lead, digital product designer; 25 interviews). These informants either had experience with multi-disciplinary project work or were directly involved in the coordination and digitalization of knowledge collaboration in projects.

The first author conducted the interviews using a semi-structured interview guide aimed at gathering retrospective and real-time accounts of how and why project members searched, stored, and retrieved the expertise needed in their daily project work. Questions addressed the value of situated expertise (e.g., 'What (if any) is the value of external expertise for projects?') and different elements impacting situated expertise development (e.g., 'Do you actively seek to maintain and build your awareness of others' expertise? How?'; 'What technology, if any, do you use to find an expert?'). The interviews were, however, not limited to the interview guide, but of a more conversational nature, allowing for new turns in the discussions. The interviewees were also invited to show how they navigated digital tools. For instance, we observed that informants often used MS Teams' organizational chart function to access different experts' hierarchical connections and contact information.

3.4. Data analysis

Interview transcripts, field notes, and documents were unified in the qualitative data analysis software NVivo 20, within which we inductively explored the research phenomenon. Fig. 3 visualizes the coding tree that represents how we systematically abstracted the data into more general theoretical patterns.

Informed by the Gioia methodology (Gioia et al., 2013), we started the data analysis process by inductively coding different arguments reflecting the value of cross-boundary meta-knowledge and different elements contributing to situated expertise development. These first-order concepts (Gioia et al., 2013) were marked with simple descriptive phrases, the interviewee's language, or a combination of both (Glaser and Strauss, 1967) (e.g., 'they are the experts where we are not'). Comparing and grouping the first-order codes led to the development of theory-based themes (e.g., 'intragroup situated expertise,' 'strategy').

In our data analysis, we constantly moved back and forth between our extensive list of first-order codes and second-order themes. The first author executed the initial coding, while the second author and two other colleagues acted as challengers of the data interpretations and emerging themes and dimensions. At the later research stage, we also sought feedback from experienced interviewees to validate our data analysis and clarify some contradictory findings, such as the need for front-end expertise formalization. This iterative data analysis process resulted in two aggregate dimensions—permeable expertise boundaries in projects and situated expertise development—that helped understand how the interviewees experienced project group expertise boundaries, and how and why they developed situated expertise systems crossing these boundaries.

Importantly, we anonymized all the quotes so as not to reveal the interviewees' identities [company name, interviewee's realm (M–management and commercial specialists; E–engineering leaders and engineers; D–digital leaders and digital specialists), and a randomized interview number]. For instance, 'Alpha E.1' refers to an engineer at Alpha.

4. Results

This section presents the findings that reveal the permeability of project groups' expertise boundaries, followed by those on elements impacting situated expertise development in the intra- and interorganizational project context.

4.1. Permeability of expertise boundaries in project work

Our data analyses unveiled the notion of 'who knows what' and 'who knows whom' networks. The interviewees' experience with situating expertise in projects coalesced around four expertise locations reflecting the permeability of group expertise boundaries: intragroup, organizational, interorganizational, and digital situated expertise (see Table 1 for illustrative quotes).

Intragroup situated expertise and its importance were evident in all the interviews. Alpha's front-end project groups comprised a wide array of multi-disciplinary experts from more than 20 departments. The interviewees, specifically project managers and engineering leaders, voiced the value of knowing each other's expertise within the project groups. An engineering leader remarked on a practice of mapping each other's competencies, strengths, and weaknesses. This practice also applied to project and customer–supplier contexts and helped project members 'play each other better' and create trust in the project environment. Our analysis, however, revealed that the interviewees had more 'general' expertise awareness or meta-knowledge about the bulk of the group members and in-depth meta-knowledge about 10–15 people with whom they closely collaborated.

Our analysis revealed the criticality of *organizational situated expertise*. In front-end work, project groups denoted temporary expertise pools, while their home departments—from which the project groups were assembled—represented stable expertise pools (Mell et al., 2022). An Alpha manager noticed that being a part of the front-end organization meant being an essential organizational 'asset' who weaves both technical expertise and 'personal networks' into project work (Alpha M.25). Engineers and managers at Alpha and Beta had a variety of in-house expertise connections, particularly across projects A, B, and C, which they utilized in their daily project work. The need to develop and maintain organizational situated expertise was also related to the recent merger that had enlarged 'time pressure and work scope' (Alpha E.46) for Alpha's project group members. As a result, it necessitated cross-legacy situated expertise between people with subsea production systems and flowlines backgrounds.

Reflecting the value of *interorganizational situated expertise*, the interviewees stressed that performance in both cost- and schedule-driven projects hinged on customer–supplier expertise systems, especially in the context of small operators such as Beta. Due to the customer–supplier expertise diversity, it was critical that 'the engineers on the Beta site [were] talking directly to the Alpha engineers' (Alpha M.19) because project and study managers did not have the expertise to manage that individual interaction level. The efficiency gained from knowing 'where to go for solutions' (Beta E.9) was prominent in the front-end project phase with limited contractual obligations. In this 'flexible' project phase, customer–supplier filed–specific design discussions hinged on trustful expertise systems and their effective utilization to 'calibrate' the needs: 'If we're going to have something project- and reservoir-specific, we need the client' (Alpha, E.34). Crossing organizational expertise boundaries was particularly critical in project A, where Alpha delivered an innovative solution of electrically trace-heated pipelines tailored to a specific oil reservoir. In this project, Beta contributed critical expertise that Alpha's project group(s) lacked.

Apart from human-based knowledge locations, the interviewees, especially those at the intersection of the engineering and digital domains, claimed that individual and group work in projects was contingent on *digital situated expertise*, alluding to the awareness of 'how to share, how to upload, where, what, and how' (Alpha E.21). In contrast to two-way human-based meta-knowledge, digital situated expertise was non-reciprocal, referring to individuals' one-way awareness of technologies' functionality.

4.2. Situated expertise development

Our analyses revealed four central elements affecting situated

Table 1
Extract of the structured data analysis: expertise boundaries permeability in projects.

Illustrative quotes	First-order codes	Theme
Like Mother Teresa said, 'Do you know your people?' … Last week, we started to map the competencies, very generically. It's extremely important to know each other's strengths and weaknesses … because when everybody knows that you're good at that … you kinda create a level of trust, and you can play each other much better.… It is extremely important in the organization and also in [the] interaction with the client—if you have a good working relationship with a client for 2, 3, or 4 years, you should know each other in terms of competencies as well, so you can contribute in a better way. (Alpha E.20)	Knowing each other's strengths and weaknesses helps 'play' each other better	Intragroup situated expertise
We have to trust, which is a very important factor when you're running a project. You have to trust people— that they're the right people in the right positions. You can't go off to [check on] people. (Alpha E.34)	Need to trust people in projects	
You aren't only bringing in technical expertise.… You're getting recruited into the front end … because of your ability to collaborate and your network. So, you know your organization. You're an asset. (Alpha M.25) *All the project members… have to go back to the base organizations [departments] to ask for guidance on how to do things or [on] what the rules [and] processes are for certain things. (Alpha E.44)*	Knowing the organization makes 'you an asset'	Organizational situated expertise
The most important [thing] is to get to know whom you can ask. When we started project A, we didn't know who anyone was [in Alpha 2] … but that has improved … [with time being] spent to build the bridges. (Alpha E.33)	'Whom you can ask' across legacies	
All field developments are different. But … there is a potential efficiency gain if you know each other [and] where to go for solutions. (Beta E.9) *There're a lot of various disciplines that need to come together and talk about what are the main difficulties and how we can handle those. (Beta M.1)*	Efficiency gain from knowing 'where to go for solutions'	Interorganizational situated expertise
In terms of equipment and delivery, they [Alpha] are the experts where we [Beta] are not. So, the earlier they are involved, the more they are involved, the more opportunity you have to get most of the equipment for the job, thereby reducing the cost. (Beta E.17) *We [Beta] have needs, but we [do] not have [the] people, the knowledge to develop what is required. So, [there needs to be] collaboration with a contractor. (Beta E.10)*	'They are the experts where are not' *[In project A, Beta was] the client but [also] contributed expertise. They secured … the resources we should have had on our side from the start. They got some of the key people in Norway with the knowledge that was required to build this kind of system [electrically trace-heated pipelines]. (Alpha E.33)* Customer–supplier expertise systems for innovation	
[The project's front end] is a bit of a mix between pre-FEED and FEED activities—you [use] XaitPorter … Team Centre … SAP, and ITU. You need to be skilled and able to operate all these systems. (Alpha E.35) *There is somewhat of a barrier [to] people getting familiar with the [digital] tools and knowing how to share, how to upload, [and] where, what, and how to set atomization on the different files. On a regular basis, I see that just not being aware of the functionality limits what people do. (Alpha E.21)*	Need to be aware of and skilled in digital technologies	Digital situated expertise
I don't have a clue who is working on the project to be honest, because we are a matrix organization, meaning that … those who are doing some slight product-specific parts of one component 'write hours' on our account, and that's a lot of people. (Alpha E.14) *We're very siloed … [In a project,] you pull [people] out of their environments into this group that is going to deliver across [silos]. Then, [you] will be bumping up against all of these silos—our structures, our processes, and even our [digital] tools, which are optimized for those structures. (Alpha E.44)*	Fragmented expertise systems in projects	Fragmented situated expertise

expertise development within and across group expertise boundaries: strategy, structural design, interaction molding routines and roles, and digital boundary objects.

4.2.1. *Strategy*

Although the interviewees voiced the value of awareness of others' expertise, the data analysis revealed the lack of strategic 'ownership' of situating expertise in Alpha and Beta. There were no companywide strategies targeting situated expertise development in projects. A common suggestion, however, was that to ensure the permeability of project group expertise boundaries, management had to claim strategic responsibility to familiarize people with the expertise scattered across home and customer project organizations. In the customer–supplier context, the shadow of the future (Ligthart et al., 2016) related to the strategic alliance contributed to interorganizational and cross-project situated expertise development due to Alpha's repetitive engagement in Beta's projects.

> The intention of [the] alliance … [is] to help in terms of collaboration—to get to know each other as organizations and … build trust. I think the groups working on projects B and C are very much aware that this is not the last project. (Beta E.9)

4.2.2. Structural design

We further observed an essential element of *organizational and group design.* In particular, substantial group and organizational size both fostered and impeded the development and utilization of situated expertise in projects. Expertise diversity in large Alpha project groups was argued to be cardinal for knowledge-intensive oil and gas engineering projects, where 'a lot of [technical and commercial] expertise' needed to be fused to design an economically and technically feasible solution (e.g., subsea 'Christmas tree' structures). At the same time, we observed that due to the substantial group size, the bulk of the interviewees were not aware of the exact number of project group members or their expertise, but rather had in-depth awareness of a smaller range—10–15 people—of the project group members. At the organizational level, we observed that although developing expertise systems 'took a long time' in Alpha with more than 20,000 employees, the matrix organizational structure ensured the flexibility of expertise flows within and across project groups—engineering leaders could 'easily [draw] on the specialists and the competencies based on the need [they had]' (Alpha E.12). In the customer–supplier context, Alpha's project members noticed that the development of expertise awareness was 'easier' with medium-size Beta compared to large oil operators that have substantial 'in-house' expertise.

Spatial proximity also aided access to 'tribal' expertise by facilitating observation and informal communication such as 'coffee-machine' chat: 'To know the competencies, you have to see how they [employees] perform' (Alpha E.14). Spatial proximity contributed to the development of organizational situated expertise: 'Coming from Alpha 2, it's more difficult for me to navigate in Alpha 1 … but sitting with Alpha 1 …. made my day easier' (Alpha E.39). An Alpha project leader noted that willingness to commute between company sites (a one-hour drive) was a primary recruitment condition in project A because the network density decreased significantly between locations. In the customer–supplier front-end context, spatial proximity was not listed among the critical elements because Beta's employees were co-located with Alpha only after the contract was awarded: 'When you've signed a contract … you're in the same boat—we're working on the same floor, see[ing] each other every day, drink[ing] coffee, and shar[ing] information' (Alpha E.20).

Several engineering leaders voiced the role of *structural (in)stability* for situating expertise. Since individuals in Alpha were 'kept too long in one area of expertise,' 'mov[ing] people across the organization' (Alpha E.22) was an effective mechanism for strengthening situated expertise for integrated project delivery. At the same time, we observed that even experienced employees struggled to maintain or stay up to date on organizational situated expertise. Alpha's E.33 stated, 'It's still the old legacy organizations that you know, and you know what people do, and you know what competencies they have.' Due to the organizational structural instability and discontinuous customer–supplier project relations, project structural stability was seen as a critical element for situating interorganizational or interproject expertise: 'I have worked with Alpha on numerous pre-FEED, FEED, tenders, and contracts over the years.… I have a good understanding of the external people and expertise' (Beta E.10).

4.2.3. Interaction molding routines and roles

Alpha's management team and learning organization arranged an induction day course and mentor, buddy, and onboarding programs to assist employees, particularly newcomers, with basic knowledge about Alpha's portfolio as well as the potential (non-)digital sources of expertise in Alpha. However, few project members mentioned these *HRM practices* as points of situated expertise development, mainly due to the idiosyncratic nature of project collaboration limited by time, cost, and quality constraints.

While HRM practices had a limited impact on situated expertise development, *recruitment and structuring routines* played a prominent role in situated expertise spanning across group expertise boundaries. Autonomous resource recruitment or the 'handpicking' of project group members was mentioned as critical for expertise development: 'In project A, I was quite lucky … to be able to choose my group. I chose people who are competent [and] experienced.… Normally, you cannot choose yourself' (Alpha E.29). In line with the abovementioned value of project structural stability, managers and project managers in Alpha and Beta noticed that the 'reuse' of human resources in the value chain and across projects contributed to successful expertise situating: 'The most effective projects are the ones where we reuse the same groups, the same people who know each other, who trust each other' (Beta M.27). Among structuring routines, Beta interviewees mentioned 'mirroring' the structure of Alpha's project groups: 'We tried to mirror the organization of Alpha so that our system engineer talks to [its] system engineer, our subsea engineer talks to [its] SPS engineer, etc.' (Beta E.32).

Although project group members often self-spanned group expertise boundaries when situating expertise within their home departments, our data analysis unveiled the criticality of *boundary-spanning roles.* The general impression from the interviews was that experienced project managers and department leaders, as centrally positioned boundary spanners (Olabisi and Lewis, 2018), often connected project group members to diverse experts in both Alpha and Beta, thereby contributing to the development of expertise systems crossing project group expertise boundaries. For example, project group members remarked that if there was a 'crisis with something' (Alpha E.46) that required contacting a specific Alpha department, project and department leaders were key knowledge brokers. Alpha's E.14 voiced the value of boundary spanners for project work, 'That's one of, I guess, my strengths, that I have a broad network here within the company [Alpha] and know where [I] need to go to solve issues.' At the organizational level, there was a consensus that Alpha's subject matter experts and chief engineers support individuals with specialized knowledge on, for example, materials, welding, or hydraulics, and actively span expertise across the organization. In contrast, a consensus on the role of salespeople was missing. Salespeople saw their role as 'mak[ing] connections' across Alpha and Beta project members who were often uncomfortable with 'being transparent' (Alpha M.19). Alpha's engineers, in contrast, perceived salespeople and account managers as bottlenecks in interorganizational expertise situating: 'We are often dependent on the middleman. That is often the sales department.… That is the challenge [—] to involve the sales [… and] business development group well enough' (Alpha E.44). These contradicting beliefs can be linked to the weak embeddedness of salespeople in the project groups and customer–supplier collaborative relations.

In the discussion on interaction roles and routines, the interviewees voiced the value of *multifaceted trust* since they were more likely to access and use expertise from a trustworthy source. The interviewees remarked that despite the high-level trust between Alpha's and Beta's engineers 'on the technical level,' environmental volatility (e.g., fluctuations in the project and organizational human resources) required the constant 'rebuilding' of interpersonal and organizational trust since new project entrants 'often started with mistrust.' Considering 'digital skepticism' within the companies (e.g., 'I don't like clouds, I'm losing control' [Alpha E.39]), Alpha's D.21 remarked that trusting situated expertise required the intertwisting of artifacts and humans: 'We need to make sure that it's not all machines. The human aspects need to be considered.'

4.2.4. *Digital boundary objects*

In line with the abovementioned digital situated expertise, our data analysis unveiled two other intertwined roles of digital technologies in the development of situated expertise systems across project group expertise boundaries: (1) digital communication means and (2) expertise and knowledge navigation. Managers and engineers formally and informally stored, shared, and searched for expertise and experience through multiple digital technologies. Due to the limited contractual regulation of collaboration in the front-end project phase, multilevel digital communication was often ad hoc and occurred via 'conventional' digital tools for knowledge collaboration, such as clouds, MS Outlook, and MS Teams.

In the discussion on *expertise-navigating repositories*, multiple digital technologies in Alpha were recited for finding and accessing a particular expert at a project's front end. Some of the most frequently mentioned tools were Bridge forum, a global business management system (GBMS), the iLearn e-learning database, MS Teams, PoP intranet, and Yammer enterprise social networks. The Bridge forum allowed Alpha employees to 'gain knowledge' and find an expert in different 'project-related' networks (e.g., hydraulic networks, subsea production system networks). Situated expertise systems were developed through these digital boundary objects, enabling vicarious learning (Leonardi, 2015) based on observing others' communication in the forum. The GBMS and project organizational charts stored in clouds also functioned as digital boundary objects for building situated expertise. In contrast to recent studies on enterprise social networks (Engelbrecht et al., 2019; Leonardi, 2017), we revealed that Yammer and PoP were often used for '(in) formal storytelling,' rather than for expertise situating. Not least, these objects were seldom used by project members in their daily work due to time pressure. MS Teams, in contrast, was frequently mentioned and used during interviews for navigating between Alpha's experts. However, this digital boundary object—designed for cross-boundary communication—provided only hierarchical networks rather than an expertise overview.

In the customer–supplier context, aside from a single case of being contacted by the customer via LinkedIn, no digital tools were mentioned as possible expertise repositories in the front-end settings: 'You use your own experience [to find an expert in Beta].… I don't have an organization chart from Beta that says, "[Do] you want to find a guy with this skill set?—He is hooked." No. And the client does the same' (Alpha E.12). Similarly, despite the presence of an extensive e-learning database, the interviewees often built digital situated expertise via colleagues who could demonstrate the functionality required 'quicker than taking a course.'

In line with digital expertise navigation, the role of digital technologies as *knowledge-navigating repositories* was another prominent topic of discussion. Alpha and Beta informants recited several digital technologies that helped them store and retrieve project-related knowledge. Digitalized lessons learnt were often mentioned as objects safeguarding intra- and interorganizational project-related knowledge. In these digital boundary objects, placed at the interorganizational and project boundaries, Alpha and Beta project experts could store and retrieve knowledge from previous projects and find an expert who codified lessons. The engineers in both companies commended digital lessons learnt as a boundary object that could advance the (co)development of 'next-generation systems' (Alpha E.14) by systematically representing project experiences and reducing the danger of making 'old' mistakes.

> In the project, the parties will [hold] lessons learnt workshops, both internally and together. These should be used in the future to maintain good practice and improve the scope…. [PIMS Lessons Learnt Module] is a very useful tool if it is followed up correctly, maintained, and used by future project groups (on both sides). Historically, this has been difficult to achieve. (Beta E.10)

> It's a good idea [to store experience digitally] because … it is very people-dependent. We drilled the reservoir. We had quite a lot of important experiences [of] things that we didn't do well. Luckily, the people are here now … but if it were a completely new group, we'd probably make the same mistakes again. (Beta E.6)

In line with the discussion on the favorable role of digital boundary objects in projects, many project members and even digital leaders voiced a clear preference for retrieving knowledge from people. An Alpha engineer commented, 'You can capture the essence of a lesson [in a tool]. But if you really want to understand how things are done and avoid [making] the same [mistakes] again, you need the person who actually experienced it' (Alpha E.47).

The interview data and observations revealed several limitations of digital boundary objects for expertise navigation. Leonardi (2017) argued that employees are reluctant to formalize their expertise because they believe it is useless for coworkers. In our study, the interviewees struggled to formulate their areas of expertise: 'I kinda struggle to define my competency. It's an overload—a lot of technical details. I know how projects work, and I know how context works because I live my life in between technical and contract[ual] [aspects]' (Alpha E.11). Moreover, digital boundary objects with current capabilities and semantics were experienced as time-consuming and not able to provide the 'high granularity' needed for expertise navigation in the context-specific front-end project work.

> Normally what you're looking for is not a geophysicist. It's the one that has been dealing with the software in this illumination problem. … That kind of detail you don't see in the CV [database]. [You only understand] that by communication. (Beta M.27)

We also observed a lack of systematic approach (i.e., different databases and formats) and limited information visibility of the digital boundary objects: 'Now we have to check the G-Drive, PowerPoint, … Excel sheet. It's kind of not a system, per se—it's difficult' (Alpha E.45). Interestingly, we observed that an experienced project member spent half an hour finding an expert on an organizational project chart, while those using MS Teams quickly found people in Alpha but could not review their expertise. Therefore, interpersonal networks often supplemented digital technologies in 'time-crunched' front-end project work: '[MS] Teams can help me partly, but then I have to do some more research—maybe make a phone call' (Alpha E.35).

5. Discussion

Given the increasingly complex and digitalized project work (Sydow and Braun, 2018), it is vital to gain a deeper understanding of group expertise boundaries and their impact on the development of expertise systems crossing multiple boundaries (Dibble and Gibson, 2018). By adopting an open perspective (Ancona and Caldwell, 1992; Mell et al., 2022) on expertise systems in complex project work, this paper offers insights into the permeability of group expertise boundaries and the development of open situated expertise systems in knowledge-intensive engineering projects.

Our findings underscore the role of open systems of situated expertise scattered among individuals, groups, and digital technologies both within and beyond project group boundaries. In particular, our study shows that in addition to the group and organizational expertise pools, individual and group performance in projects depends on expertise situated in the collaborating customer or supplier organization and digital situated expertise. The latter refers to individuals' awareness of the availability, functionality, and location of digital boundary objects that can be utilized for individual and group performance. This open view on situated expertise extends the traditional focus beyond intra-group expertise boundaries, highlighting the integration of customer–supplier expertise systems in the context of rising project networks, multi-project organizing, and the growing significance of human–machine collaboration (Anglani et al., 2023; Fiore and Wiltshire, 2016; Jarvenpaa and Välikangas, 2020). These findings demonstrate the permeability of group expertise boundaries, where group memory extends beyond traditional group boundaries, enriched by a broader environment. However, extra-group situated expertise appears more centralized than intragroup expertise systems, reflecting the fragmented nature of situated expertise systems in temporary project organizing.

In response to the call to explore the role of permeable group expertise boundaries in shaping expertise systems (Mell et al., 2022), we identified four elements supporting the development of open situated expertise systems in complex engineering projects (see Fig. 4).

Firstly, the lack of formal *strategic* responsibility for situating expertise leads to self-regulated situated expertise development within permanent and temporary organizations. Interorganizational collaborative strategies (e.g., strategic alliances), in turn, create shadows of the past and the future (Ligthart et al., 2016), which strengthen the value of building and maintaining cross-organizational expertise systems over the long run.

Secondly, our findings suggest that *structural design* lays the ground for situated expertise development among temporary coalitions of project experts embedded in time and space (Steen et al., 2018; Sydow et al., 2004). While spatial proximity unpacks (in)formal interactions facilitating situated expertise development, group and organizational design (e.g., a project organizational structure and large collective sizes) provide expertise flexibility but, at the same time, constrain expertise systems' density. Our results also suggest that structural instability—inherent in temporary organizing—causes expertise silos, hampering the development of situated expertise systems by requiring constant updates, whereas structural stability enlarges group members' ego-centered situated expertise and multifaceted trust.

Thirdly, our findings reveal the importance of *interaction molding routines and roles*. Our findings suggest that recruitment and structuring routines (e.g., autonomous recruitment, people reuse, cross-site rotation, group mirroring) strengthen situated expertise by exploiting existing and reactivating latent expertise systems. Aligning with earlier studies on expertise and group boundaries (Kislov, 2018; Mell et al., 2022; Olabisi and Lewis, 2018), our findings show that expertise situating logics in complex project group work are interwoven into boundary-spanning roles. Our results suggest that boundary spanners who are strongly embedded in the project context and have in-depth expertise (e.g., project leaders, subject matter experts) actively span the group expertise boundaries, while weakly embedded boundary spanners with general knowledge (e.g., salespeople) both span and hinder situated expertise by transferring bits and pieces of information and limiting the awareness of original expertise locations. This finding, in contrast to Dibble and Gibson's (2018) proposition, suggests that group members' core positioning and full-time assignment to the group positively impact group expertise boundary permeability. This means that those who possess more extensive meta-knowledge and are more proactive tend to be more effective at orchestrating expertise across group boundaries. Moreover, front-end situated expertise—governed by relational rather than contractual governance mechanisms—hinges on cumulated or multifaceted trust (Matinheikki et al., 2016) in individuals, organizations, and digital technologies.

Lastly, adding to earlier studies on extra-group expertise systems (Bachrach et al., 2019; Peltokorpi, 2014), our analysis shows that *digital boundary objects* (Alin et al., 2013; Chang et al., 2013; Nicolini et al., 2012) can mediate boundary conditions and facilitate situated expertise development by enabling experts to make their expertise and experience visual and accessible. Digital boundary objects contribute to the permeability of group expertise boundaries and situated expertise development in project work through their trihedral role—digital situated expertise, means of communication, and expertise- and knowledge-navigating repositories—when project-related expertise and experiences are formalized and remain in the collective 'digitalized' memory as they are discussed, shared, and stored. Nevertheless, in contrast to previous studies (Engelbrecht et al., 2019; Leonardi, 2015), our findings suggest that digitalization of situated expertise development remains limited in cross-boundary project work. In our study, we uncovered several aspects precluding expertise digitalization, such as a lack of standardization, intricate expertise formalization, low digital trust, and the dereliction of expertise strategies. Not least, the use of digital boundary objects in project work is constrained by temporariness (Sydow and Braun, 2018) that predetermines the flow and pace of

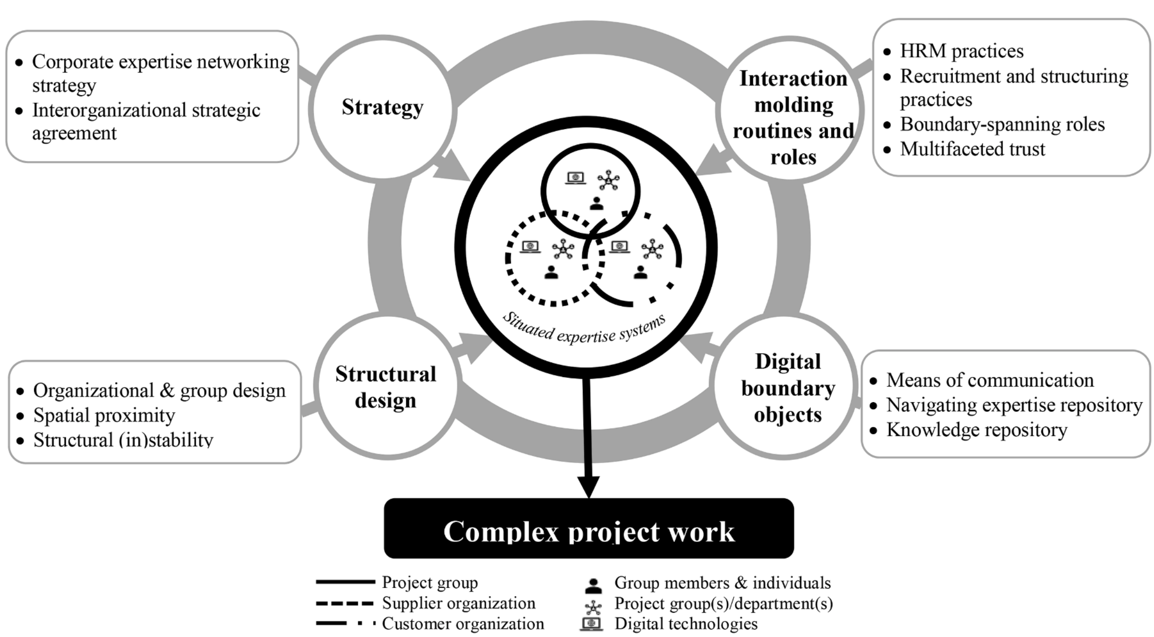

Fig. 4. Development of open situated expertise systems in complex project contexts.

situating expertise. As a result, situated expertise development in complex projects remains contingent on interaction molding roles of boundary spanners as the central cogs (Mell et al., 2022) of developing and maintaining temporary expertise bridges (Zhao and Anand, 2013) between knowledge seekers and contributors in complex project work.

Hence, based on the holistic analysis of the expertise systems crossing multiple boundaries in complex project work, we identified four elements contributing to the development of open situated expertise systems. Despite these elements' complementarity, their explanatory power varies between intragroup and extra-group expertise systems. The former hinges on structural design and roles, whereas the latter is contingent on structural stability and boundary spanners. Multifaceted trust is, however, critical for both types of expertise systems in the digital age. Digital boundary objects also mediate expertise boundaries in both systems via their trihedral role, but underlying barriers still preclude situated expertise development via digital boundary objects.

5.1. Theoretical implications

By embracing an open perspective on expertise systems in projects (Ancona and Caldwell, 1992; Mell et al., 2022), this study offers threefold theoretical implications.

First, scholars have called for qualitative studies on extra-group meta-knowledge (Hsu et al., 2016; Olabisi and Lewis, 2018) and individuals' perceptions of group boundaries (Wimmer et al., 2019). We contribute to the meta-knowledge and group expertise literature, dominated by quantitative studies (Heimstädt et al., 2023), by providing important qualitative insights into the usefulness of considering the variation in group members' meta-knowledge across project group, organizational, and collaborating partner contexts. In particular, this article offers an open theoretical perspective on situated expertise development and use in complex project work, referring to a shared situated expertise system that is based on a collective awareness of the unique expertise and functionality of individuals, groups, and digital technologies scattered within and across project group boundaries. These insights further suggest that the traditional research focus on group expertise boundaries may limit our understanding of expertise use within projects and organizations. Instead of viewing project groups as clearly bounded expertise systems, we need to shift toward perceiving them as 'open' systems with thin, permeable boundaries (Workman, 2005, 2007), allowing expertise inflow and outflow, thereby impacting the development of open expertise systems in projects. Moreover, in response to the call to explore the positive side of group boundary permeability (Dibble and Gibson, 2018), we provide empirical evidence for the usefulness of permeable project group expertise boundaries for the development of idiosyncratic, innovative products and services, in our case in the front-end project phase. Hence, by explicating the value and development of permeable group expertise systems in the project context, our findings deviate from the assumption that permeability of group boundaries is harmful (Hackman, 2002), contributing to a growing open view on expertise systems in organizations (Hsu et al., 2016; Mell et al., 2022; Mortensen and Haas, 2018).

Second, this study advances project studies and literature on group boundaries and meta-knowledge by offering insights into elements contributing to the continual process of situated expertise development, which facilitates the permeability of group expertise boundaries in the temporal project systems. Previous studies have explored only specific elements as central cogs of situated expertise in the intergroup context, such as boundary-spanning individuals (Mell et al., 2022). Our model, in contrast, provides a broader view on what elements impact the development of open situated expertise systems in projects and reflects the changing nature of project work spanning multiple expertise boundaries in the digital age (Anglani et al., 2023). Austin (2022) identified the combination of knowledge awareness, help-seeking actions, external benchmarking, and blurred boundaries as necessary to convert accurate group meta-knowledge into high-quality extra-group expertise systems. Our findings add nuances to this research by showing that boundary spanners play a critical role in face-to-face expertise coordination and an ancillary role (Olabisi and Lewis, 2018) in digital expertise situating. At the same time, boundary spanners' meta-knowledge alone can be insufficient to facilitate situated expertise development and must be supported by other elements. In particular, we suggest that intragroup situated expertise development is contingent on structural design and interaction molding routines, whereas the development of extra-group situated expertise systems hinges on interaction molding boundary-spanning roles, digital boundary objects, and multifaceted trust. These advances precede inquiries into the interplay of the formal and informal as well as human and non-human elements associated with group expertise boundary permeability (Dibble and Gibson, 2018; Hanelt et al., 2021), thereby paving the way for future conceptual and empirical research. Future research can build from this exploratory study to examine agentic decisions and characteristics of boundary spanners to understand how individuals leverage their structural context to improve situated expertise. Such a study could use a method of measuring direct expertise awareness in a project network akin to the method used by Austin (2003) to directly measure transactive memory systems in natural organizational groups.

Finally, this study contributes to the growing literature on expertise digitalization (Anglani et al., 2023; Fiore and Wiltshire, 2016) and the use of digital boundary objects in projects (Alin et al., 2013; Azzouz and Papadonikolaki, 2020; Chang et al., 2013; Korotkova et al., 2023). We extend the understanding of how digital boundary objects contribute to the development of open situated expertise systems in project work, an aspect that has been previously overlooked (Engelbrecht et al., 2019). Leonardi (2015) presumes that digital boundary objects may facilitate vicarious expertise learning by observing ambient digital-based communication. We also show that digital boundary objects can advance situated expertise by allowing for vicarious learning, active searching for content (Oostervink et al., 2016), scanning others' profiles (Ellison et al., 2014), and posting questions. At the same time, we provide critical insights into the role of digital boundary objects for situating expertise—an aspect that has received scant scholarly attention (Heimstädt et al., 2023). Our results suggest that the protracted digitally enabled expertise situating process may contradict the iron triangle constraints of time, cost, and quality in the temporary project context (Ligthart et al., 2016; Sydow and Söderlund, 2022). Furthermore, the present study suggests that although digital boundary objects mediate project group expertise boundaries in complex engineering work, there is an essential qualitative difference between interpersonal expertise and digital boundary objects for expertise coordination. Boundary spanners are key to helping expertise seekers find expertise holders. These actors are particularly important in situations where new knowledge needs to be generated due to their ability to understand the nuances of the need. Digital boundary objects lack this knowledge brokerage step. This limitation may fundamentally change how such expertise is accessed and used. More broadly, these findings contribute to a more holistic view of how digital boundary objects fit within meta-knowledge research (Fiore and Wiltshire, 2016) by showing that situating expertise via digital boundary objects is rather limited in temporary project systems.

5.2. Practical implications

Our study also offers several practical implications. Although cross-boundary expertise is a key resource for leveraging competitive advantages (Hetemi et al., 2022; Mell et al., 2022), project-based collectives often struggle to recognize, harness, and integrate such expertise into a cohesive system of collective knowledge (Mohammed et al., 2021). Our study suggests that to develop and coordinate expertise systems effectively, practitioners need to consider situated expertise in project work in the form of members spanning their meta-knowledge across project group expertise boundaries. This ability to cross group expertise boundaries might result in tangible implications in the form of efficiency gains and innovations.

Our study offers a practical contribution for managers and project managers in terms of understanding how different elements affect situated expertise development in the knowledge-intensive engineering project context. To achieve well-developed situated expertise systems, practitioners need to approach the four elements identified holistically to avoid the halo and horn effect of expertise situating in complex projects, as well as to ensure that the permeability of group expertise boundaries enhances rather than reduces group outcomes. The debated role of boundary spanners also suggests that practitioners, especially those operating in turbulent project environments, should scrutinize the positions, knowledge, and accessibility of central boundary spanners to eliminate potential situated expertise fragmentation.

A common problem for project organizations is recording and retrieving project-related expertise and experience because paper-based remembering is highly labor-intensive (Blagoev et al., 2018). Our study indicates that digital boundary objects can offer project members a possible solution to this difficulty. Practitioners, therefore, should consider routinizing digital technologies for situated expertise development to profit from them in terms of creating completive advantages and improving project performance. In line with the aforementioned qualitative difference between interpersonal and digitized expertise repositories, practitioners need to reconsider their strategic approaches to situating expertise and address the drawbacks of expertise digitalization.

5.3. Limitations and future studies

As with other research work, it is necessary to consider the limitations of this study that call for future research. This study's primary limitation stems from its reliance on a single case study encompassing two collaborating organizations within specific contextual conditions. Our research focused on the knowledge-intensive oil and gas context, notable for its demanding prerequisites of education, experience, and creativity among its members. The contextual conditions in this case study have also shaped a unique trajectory of digitalization, manifesting in a unique set of digital boundary objects characterized by specific social meanings, affordances, and consequences for situated expertise (Hanelt et al., 2021; Leonardi et al., 2019). Such a context-specific study design raises questions about its generalizability, emphasizing the need for replication and further research extension. Future studies can build on this qualitative study to explore the permeability of group expertise boundaries and elements impacting the development of situated expertise systems in different contexts. These contexts may include less knowledge-intensive and more routine project work settings, as well as supplier collaboration with a broader range of external project stakeholders, such as vendors, competitors, and R&D institutions. This inquiry is particularly pertinent when exploring the role of digital boundary objects in the development of open situated expertise systems, given that digitization can take different forms and levels of complexity in varying contexts.

This study applies a structural perspective to group expertise boundary-spanning in the complex project context. Future studies can explore the role of boundary spanners in the development of situated expertise from an agentic perspective (Mell et al., 2022) by focusing on boundary spanners' personal characteristics, such as openness, intrinsic motivation, and the level of technological optimism. Moreover, we focused on the positive side of group boundary permeability, while project group members operating in the mixed-motive customer–supplier context (Jarvenpaa and Majchrzak, 2008) often need to simultaneously share and protect expertise. Future studies can thus explore boundary buffering and reinforcement strategies (Kislov, 2018), embracing elements and practices through which project groups close or set boundaries to protect their unique expertise. Not least, our findings identify a need to deepen our understanding of how temporariness affects the development and richness of open expertise systems.

6. Conclusion

The increasingly dynamic interplay of digitalization and knowledge intensity in interorganizational projects necessitates a critical reevaluation of the traditional bounded approaches to expertise systems in projects. Adopting an open perspective on expertise in projects, this qualitative study explores the role of group expertise boundaries in situated expertise development, with a specific emphasis on digital boundary objects as contextual conditions for situating expertise in complex oil and gas engineering projects.

Our findings show the significance and benefits of the permeability of group expertise boundaries in nurturing the development of open situated expertise systems. These systems denote a shared knowledge system based on a collective awareness of the unique expertise and functionality of individuals, groups, and artifacts scattered within and across group boundaries. Such open, socio-technical expertise systems are specifically critical for the front-end (co)development of idiosyncratic, innovative products or services.

Furthermore, our analysis identifies four key elements that collectively contribute to the development of open situated expertise systems in complex project work: strategy, structural design, interaction molding routines and roles, and digital boundary objects. While digital technologies continuously serve as conduits for communication and knowledge and expertise navigation, their effectiveness as digital boundary objects is hindered by underlying barriers, including a lack of a key knowledge brokerage step for sensing specific needs in expertise coordination. Therefore, despite the promising capabilities of digital boundary objects in mediating project group expertise boundaries, this study reveals a critical reliance on relational elements such as boundary-spanning roles. This suggests that the deployment of digital boundary objects for expertise situating must be aligned with the needs and realities of specific project environments to avoid potential pitfalls, such as digitally spurred over-centralization in project work.

While crossing group expertise boundaries holds promise for efficiency gains and innovation in complex engineering projects, the development of open situated expertise systems remains challenging and often overlooked in practice. Overcoming this challenge requires rethinking how expertise is curated and deployed in project settings. Drawing on empirical insights, our study underscores the importance of enabling group members to span their meta-knowledge and holistically address the identified elements to harness the benefits of permeable expertise boundaries. Specifically, establishing strategic ownership of situating expertise in projects, scrutinizing the expertise, roles, and accessibility of central boundary spanners, and routinizing digital technologies while mitigating their drawbacks are key for cultivating rich, open expertise systems in complex project work. Future initiatives should aim to enhance the digital infrastructure to support not just the transfer of explicit knowledge but also the development of open situated expertise systems that are crucial in engineering projects.

CRediT authorship contribution statement

Nataliia Korotkova: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **John R. Austin:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Conceptualization. **Ermal Hetemi:** Writing – review & editing, Supervision.

Declaration of competing interest

There are no conflicts of interest to declare.

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