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Abstract

System-level innovation problems increasingly require firms to integrate heterogeneous and distant knowledge domains, yet existing open innovation research offers limited insight into how such knowledge creation processes are shaped and orchestrated. This study examines how physical knowledge contributors (PKCs), a distinct type of open innovation intermediary, support organizations in addressing system-level innovation problems. Integrating absorptive capacity and platform research, we conduct an in-depth exploratory case study of BlueThink, a PKC that support innovation seekers by leveraging internal competencies, physical laboratory infrastructures, and a curated network of solvers.

Our findings show that knowledge acquisition, assimilation, transformation, and exploitation - the constitutive dimensions of absorptive capacity - unfold through an iterative, cyclical process involving the PKC, the seeker, and multiple solvers, rather than through a linear, firm-bounded sequence. PKCs actively participate in knowledge creation by providing a cultural and physical inter-medium that enables learning-by-doing, supports agile experimentation, and facilitates the recombination of partial solutions into system-level configurations.

We propose an interpretive model in which PKCs operate as orchestrative two-sided platforms that extend and, in some phases, temporarily substitute for the seeker's absorptive capacity. By contrasting PKCs with the more widely studied virtual knowledge brokers or digital intermediaries, this study advances our understanding of how physical intermediaries contribute to knowledge creation in complex innovation processes.

Keywords: Open innovation, Open innovation intermediaries, Platforms, Absorptive capacity, Knowledge creation, Agile product development, Radical innovation.

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Our findings show that knowledge acquisition, assimilation, transformation, and exploitation - the constitutive dimensions of absorptive capacity unfold through a recursive, platform-orchestrated process involving the PKC, the seeker, and multiple solvers, rather than through a linear, firm-bounded sequence. PKCs actively participate in knowledge creation by providing a cultural and physical inter-medium that enables learning-by-doing, supports agile experimentation, and facilitates the recombination of partial solutions into system-level configurations.

We propose an interpretive model in which PKCs operate as orchestrative two-sided platforms that extend and scaffold the seeker's absorptive capacity across organizational boundaries.. By contrasting PKCs with the more widely studied virtual knowledge brokers or digital intermediaries, this study advances our understanding of how physical intermediaries contribute to knowledge creation in complex socio-technical innovation contexts.

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1. Introduction

Over the past decades, the ideation and development of innovative products have often been interpreted as a process of integrating and recombining knowledge from different domains (Savino et al., 2017). Trends such as digitization, servitization, and sustainability have challenged traditional approaches used in product development and innovation processes (Lusch and Nambisan, 2015; Pinarello et al., 2022). Firms are faced with the imperative to identify and assimilate technologies from different, distant knowledge domains to maintain their competitive edge and foster innovation over time (Teece, 2018).

Among the models developed in the last two decades to understand and interpret the emerging challenges and approaches of innovation processes, open innovation (OI) is the most widely studied and acknowledged (Arora et al., 2016; Chesbrough, 2003; Vanhaverbeke et al., 2019; West and Bogers, 2014, 2017).

In parallel, open innovation intermediaries (OIIs) have emerged as organizations that support firms in implementing OI projects (Rippa et al., 2016; Von Nell and Lichtenthaler, 2011). OIIs play a central role in facilitating collaborative innovation among multiple stakeholders, bridging the gaps and reducing transaction costs in OI ecosystems (Yin et al., 2022; Doloreux and Turkina, 2023). Several OIIs, such as Innocentive, NineSigma, and Yet2, act as brokers facilitating knowledge transactions between innovation seekers and solvers. Verona and colleagues (2006) named this type of OIIs as Virtual Knowledge Brokers (VKBs).

The definition of VKBs implicitly introduces two dimensions of analysis and classification for studying the broad and heterogeneous landscape of OIIs. The first dimension refers to the business models adopted by the intermediary and distinguishes between Virtual Intermediaries (i.e. intermediaries operating through a digital platform) and Physical Intermediaries (i.e. intermediaries characterized by a physical presence).

The second dimension differentiates between Knowledge Brokers and Knowledge Contributors. The former category provides services supporting knowledge transactions between seekers and solvers, while the latter offers an active contribution in the generation of the new knowledge needed by innovation seekers to solve their innovation problem.

Building on these two dimensions, we distinguish four categories of OIIs:

1. **Virtual Knowledge Brokers (VKBs),** which are among the most common types of OIIs. They leverage digital assets, i.e. web-based platform, to facilitate knowledge transactions between innovation seekers and solvers (Verona et al., 2006).
2. **Physical Knowledge Brokers (PKBs)**, which are consulting or service companies offering a suite of services specifically tailored to support open innovation processes. PKBs' business model is focused on enabling the transaction of knowledge by supporting seekers identifying 'solutions' (Sapsed et al., 2007) or acting as 'innovation capitalists' (Nambisan and Sawhney, 2007). Examples of PKBs are Intellectual property consultancy (Nambisan and Sawhney, 2007a), accounting and financial service firms, law firms, talent search agencies (Lin et al., 2016), Venture Capital Funds (Jarchow and Röhm, 2019), Banks, and TTOs (O'Kane, 2018; Temel et al., 2021).
3. **Virtual Knowledge Contributors** (VKCs), whose business model is based on the use of digital, web-based platforms employed as a hub for the generation of new knowledge. Some examples of VKCs are co-creation platforms connecting designers and creative professionals, collaborative software development platform (Twyman et al., 2023), virtual community of citizens and innovators (Randhawa et al., 2017), cooperative drug discovery platforms (Ekins et al., 2014).
4. **Physical Knowledge Contributors** (PKCs), which leverage physical infrastructures such as research, prototyping, and testing laboratories, as well as internal multidisciplinary skills and capabilities, to enable the creation of new knowledge that

enables innovation for the seekers. They include institutional subjects such as Technology Parks, Incubators (van Rijnsoever, 2020), and Collective Research Centres (Knockaert et al., 2014; Spithoven et al., 2009), Innovation Hubs (Crupi et al., 2021) as well as private organizations known as Knowledge-Intensive Business Services (KIBS) (Klerkx and Leeuwis, 2009; Yam et al., 2011) and Research and Development Service Firms (RDSFs) (Li et al., 2020).

From a business model perspective, all these OIIs share two common features: on the one hand, they bring together and connect two different categories of actors (seekers and solvers), on the other they generate indirect network effects, whereby the more seekers generate more value for solvers, and vice versa (Piazza et al., 2019). These two features are the cornerstone of the so-called platform business model (Rochet and Tirole, 2003; Hagiu & Wright, 2015). Therefore, to deep dive into the role of OIIs in solving system-level problems, this study adopts platform theory as an explanatory lens.

In particular, we argue that OIIs can be usefully conceptualized as platforms, as they orchestrate interactions among distinct actors and shape the conditions under which knowledge is created, mobilized, recombined, and transferred thereby creating value as meta-organization (Kretschmer et al., 2022). While this perspective has been predominantly applied to digital intermediaries and transaction platforms, its explanatory potential for physical intermediaries remains underexplored.

Viewing PKCs through a platform lens allows us to move beyond a dyadic intermediary perspective and to explicitly account for multi-sided interactions (Muzellec et al., 2015), orchestration activities, and recursive feedback loops that characterize the process of knowledge creation and sharing taking place in system-level innovations. Without this lens, these dynamics would remain difficult to explain using traditional intermediary or transaction-based frameworks alone.

Due to their simplicity and scalability, VKBs are the category of OII that has attracted the most significant attention from industry and academia (Lichtenthaler and Ernst, 2008). However, the OI literature has raised some criticisms about their effectiveness, highlighting several limitations of the approach on which they are based, in particular their inadequacy to address complex innovation challenges. Indeed, VKBs are primarily suited to address well-defined, incremental innovation or idea generation problems, but often lack the capacity to support complex, multifaceted and systemic innovation processes (Sieg et al., 2010). As a relevant example, Simon Schneider, founder of the crowdsourcing startup OmniCompete, acquired by InnoCentive in 2012, criticized the crowdsourcing model, stating that "big industry players [...] learned that running a challenge on a crowdsourcing web portal was best for small on-the-spot issues and not systematic enterprise innovation" (Schneider, 2017).

Increasingly, companies rely on OI to face what scholars call system-level or architectural problems (Henderson and Clark, 1990), but this often leads to to innovation failures (Coccia, 2025). System-level innovation problems consist of multiple interdependent knowledge components (Natalicchio et al., 2017) which cannot be addressed separately. Because of this complexity, they have ill-defined contours (Agogué et al., 2017; Klerkx et al., 2010; Le Masson et al., 2012), and they require the integration of different disciplines (Trabucchi and Buganza, 2022) and the co-creation of radically new solutions (Carnabuci and Operti, 2013) to be solved.

From a platform research standpoint, VKBs tend to act as pure matchmakers (Rochet and Tirole, 2003), enabling transactions between seekers and solvers (Evans, 2003; Hagiu and Wright, 2015). This is why they are ill-equipped to help seekers address system-level innovation challenges.

PKCs, instead, are actively involved in the value creation and knowledge generation activities that are needed to satisfy the needs of seekers in search of a solution to system-level problems, as well as of solvers. This is consistent with recent developments in platform literature, which shifted the role of the platform providers from mere matchmakers to orchestrators of a multi-sided system of value co-creation, where any player, as well as the platform provider itself, has an active role in creating value for the whole system (Muzellec et al., 2015; Trabucchi et al., 2022). Therefore, we use platform theory not to emphasize matching or transaction efficiency of PKCs, but to unpack the interaction mechanisms through which PKCs orchestrate iterative knowledge creation processes involving seekers and solvers. In particular, we show how the physicality of PKCs (through laboratories, prototyping infrastructures, and in-house multidisciplinary expertise) appears to alter learning, coordination, and trust dynamics in system-level innovation to solve ill-defined problems, aiming to contribute to the platform literature, by exploring how a specific category of OII, i.e. PKCs, actively orchestrate the value creation process.

This study reframes Physical Knowledge Contributors as orchestrative platforms in system-level innovation contexts and, in doing so, it offers a theoretical contribution to the absorptive capacity literature. Indeed, by adopting the absorptive capacity lens, we unpack the mechanisms through which PKCs structure multi-sided interactions, enable iterative knowledge recombination, and mediate learning across organizational boundaries. Rather than proposing a general reconceptualization of absorptive capacity, we identify a boundary condition under which, in system-level innovation contexts mediated by physical intermediaries, absorptive capacity unfolds as a platform-mediated and cyclical process within this specific configuration of system-level innovation mediated by physical intermediaries. While our empirical analysis focuses on a paradigmatic case, our theoretical interest lies in identifying mechanisms that may characterize PKCs as a category, beyond the specific organizational features of the focal firm.

2. Literature overview and theoretical background

2.1. OI, OIIs, and platform business models

OI is the most widely adopted and studied paradigm in the field of innovation management (Enkel et al., 2020). Over time, the definition of OI has evolved and is now interpreted as a "distributed innovation process based on purposively managed knowledge flows across organizational boundaries" (Chesbrough and Bogers, 2014).

OIIs have emerged as a distinct organizational form that facilitates OI processes by connecting individuals or organizations seeking innovative solutions with communities of solvers and knowledge holders who can provide these solutions. These intermediaries operate as two-sided transaction platforms (Täuscher and Laudien, 2018), connecting two groups of actors, in this case the demand side (seekers) and the supply side (solvers), generating indirect or cross-side network externalities (Katz and Shapiro, 1985; Rochet and Tirole, 2003). By participating in such platforms, more seekers make the platform more valuable to solvers, and vice versa, creating a virtuous cycle that fosters the growth and proliferation of these platforms. Aligned with the transactional typology of two-sided platforms, OIIs aim to facilitate one-to-one knowledge transactions between seekers and solvers (Trabucchi and Buganza, 2022).

Figure 1 – OIIs as platforms

This platform-based model offers several advantages, with the size of the platform directly affecting its value in a virtuous cycle (Katz and Shapiro, 1985). As a result, this model achieves scalability and sustainability once it reaches critical mass (Parker and Van Alstyne, 2005), hence becoming relevant and valuable. OIIs face challenges that are similar to other two-sided platforms, such as (i) successfully launching a new platform, which requires solving a classic chicken-and-egg problem (Evans and Schmalensee, 2016), (ii) designing a dual-value proposition to provide value to different customer segments (Muzellec et al., 2015), (iii) enabling trust, community building, and personalization mechanisms, and (iv) using data extensively to drive two-sided engagement (Trabucchi et al., 2022).

Over the last two decades, several types of OIIs have emerged. The most widely studied is known as virtual knowledge broker (VKB), first conceptualized by Verona et al. (2006). VKBs typically involve matching a seeker, who identifies an innovation problem and aims to solve it, with a solver. According to recent studies, VKBs are best suited for problems that are easily accessible to solvers and can be fully described, with clear performance criteria that make solutions easy to evaluate and to screen by the seeker (Diener et al., 2020).

Research suggests that VKBs are more effective when the innovation problem they help address is well defined and the solution space is clear. Simple, clear, and well-defined problems, such as incremental innovations, can be easily addressed through delegated search strategies, such as crowdsourcing or solution contests (Afuah and Tucci, 2012; Jeppesen and Lakhani, 2010).

However, VKBs are less useful when innovation problems are ill defined, complex and interconnected (Billington and Davidson, 2013). Indeed, a different set of activities and capabilities is required to support seekers in solving these types of innovation problems, moving from reframing the problem itself to identifying solutions and capabilities in remote domains, and then conducting trials, tests, and pilots to integrate and exploit the chosen technology or set of technologies (Lichtenthaler, 2013). In these cases, physical knowledge contributors (PKCs) are likely to play a more effective role in solving innovation problems that require significant advances in the knowledge creation process (Howells, 2006).

PKCs take a proactive approach to knowledge creation and can leverage internal competencies and physical assets to support the entire development cycle of an innovation (De Silva et al., 2018; Howells, 2006). PKCs include institutional entities, such as technology parks, incubators, university technology transfer offices (TTOs), and collective research centers (Spithoven et al., 2009), as well as private organizations known as knowledge-intensive business services (KIBS) (Chiaroni et al., 2008; Klerkx and Leeuwis, 2008, 2009), idea or technology scouts (Nambisan and Sawhney, 2007), and research and development service firms, or RDSFs (Li et al., 2020).

These are examples of OIIs supporting client firms by enabling knowledge creation process, strengthening their internal capabilities and approaches to transform ideas into knowledge that is shared and generates new knowledge through recombination mechanisms (Savino et al., 2017). PKCs have been studied for their role in integrating external knowledge, serving as knowledge gatekeepers, technology spanners, technical problem solvers, and innovation resource integrators (Guo and Guo, 2013).

As physical intermediaries, PKCs can leverage three key assets that contribute to the creation of new knowledge. First, PKCs can offer seekers and solvers design and prototyping laboratories and testing facilities (Howells, 2006), allowing them to follow the NPD process from concept to industrialization. Second, PKCs have a core in-house technical expertise that enables them to provide this type of support (Spithoven et al., 2011). Third, the exchange of ideas fosters PKCs' in-depth knowledge of solvers' technologies and capabilities, creating what can be called a well-mapped solver network. Although innovation research recognizes the important role of PKCs in enabling OI processes (Howells, 2006; Nambisan et al., 2012; Ollila and Elmquist, 2011), few studies have examined how these intermediaries collaborate with their clients/seekers to create new knowledge and solve system-level innovation challenges. As a result, we still lack a process-level understanding of how PKCs actively participate in knowledge creation across the different stages of an innovation project, and how their involvement reshapes established frameworks used to study open innovation, such as absorptive capacity.

Conceptualizing PKCs as platforms also has important implications for how absorptive capacity is understood. When knowledge creation unfolds through platform-mediated interactions among multiple actors, the processes of acquisition, assimilation, transformation, and exploitation extend beyond firm boundaries and become inherently interorganizational and iterative.

2.2. OIIs and absorptive capacity

OI processes are based on the deliberate search and integration of external knowledge (West and Bogers, 2014).

The key mechanisms and challenges in creating competitive advantage by integrating external knowledge can be understood through the AC lens, i.e. the capability through which organizations acquire, assimilate, transform, and exploit external knowledge (Zahra and George, 2002). Therefore, an adequate level of AC is an enabling factor for leveraging external knowledge and creating new knowledge (Cohen and Levinthal, 1990; Robertson et al., 2012; Zahra and George, 2002). Firms can increase their AC by opening their innovation processes and activating learning mechanisms, but at the same time, implementing OI requires a firm to have a significant level of AC (Vanhaverbeke et al., 2008). In this context, OIIs can play a key role in supporting firms with limited AC to increase it and enable successful collaborative knowledge transfer processes (Chiaroni et al., 2016; Kokshagina et al., 2017; Spithoven et al., 2013). In the context of increasing technological complexity and dynamism, collaboration with OIIs allows reducing transaction costs and risk (Morisson, 2019) and facilitating technology transfer (Lichtenthaler, 2013).

Following Cohen and Levinthal (1990), several studies have extended the concept of AC that they popularized by using the resource-based view of the firm (Lane and Lubatkin, 1998; Todorova and Durisin, 2007; Zahra and George, 2002). In this study, we refer in particular to the theoretical framework proposed by Zahra and George (2002), which includes four dynamic capabilities underlying AC: acquisition, assimilation, transformation, and exploitation. Acquisition refers to the firm's ability to acquire externally generated knowledge that is critical to its operations. Assimilation refers to the firm's ability to analyze and understand information obtained from external sources. Transformation refers to the firm's ability to develop and refine routines that combine existing knowledge with newly acquired and assimilated knowledge. Finally, exploitation refers to the structural, systematic, and procedural mechanisms that allow the firm to incorporate acquired and transformed knowledge into its operations. Zahra and George's (2002) framework distinguishes between potential AC, which includes acquisition and assimilation, and realized AC, which includes transformation and exploitation. Importantly, in this study, absorptive capacity is not treated as a static firm-level attribute, but as a dynamic process that can be partially enacted, supported, or orchestrated through the help of external actors.

VKBs have mainly been studied in relation to their ability to support potential AC. Their main tasks include identifying innovation opportunities, initiating technology transfers, and assisting firms in developing their potential AC by ensuring an appropriate match between the technology source and the recipient or innovation seeker (Kokshagina et al., 2017).

PKCs support the ability of innovation seekers to absorb and transform external knowledge by building AC at the interorganizational level and helping them take advantage of technological developments exiting outside their boundaries (Spithoven et al., 2011). PKCs can play an active role in the knowledge assimilation process by helping overcome sectoral and cultural barriers (Aquilani et al., 2016), providing specific competencies (Howells, 2006), and creating trust between solvers and seekers (Klerkx and Leeuwis, 2009). They can also enable the knowledge transformation process by facilitating knowledge recombination (Spithoven et al., 2011) and providing physical facilities for prototyping and testing solutions (Howells, 2006).

According to this perspective, PKCs appear better equipped to complement not only the potential AC of innovation seekers, but also realized AC, which becomes particularly critical in system-level innovation problems.

Relatively few studies have examined the contribution of PKCs from these perspectives, focusing on start-up incubators (Clausena and Rasmussenb, 2011; Macchi et al., 2014; van Rijnsoever, 2020), and collective research centers (Spithoven et al., 2011). While these organizations have been referred to as OIIs, their core mission is much broader and inherently limited by the nature of their institutional mission, as in the case of incubators.

As a result, we still lack empirical insights into how such organizations' shape and enact knowledge creation processes across the different phases of absorptive capacity when addressing system-level innovation challenges.

This gap in the literature can be understood when considering the accessibility of information about OIIs. Indeed, many of the organizations studied as OIIs are institutional entities i.e. universities technology transfer offices and research centers (Ollila and Elmquist, 2011), for which the disclosure of information about their work and impact on society is an essential part of their mission. As a result, many studies have focused on this type of entity.

The analysis of PKCs, is therefore more relevant to the study of how OIIs can support knowledge search, assimilation, integration, and transformation to help innovation seekers address system-level innovation challenges. This paper focuses on PKCs to address the following research questions: How can PKCs support organizations in solving system-level problems? How can they contribute to the seekers' AC and knowledge creation processes? We answer these questions by means of an exploratory, embedded case study of a paradigmatic example of PKC, BlueThink.

3. Methodology

3.1. Introducing BlueThink

In this study, we aim to enrich the existing body of knowledge with new insights from a real-world, paradigmatic case (Siggelkow, 2007). In particular, our study focuses on BlueThink (BT), a firm operating in Italy and the UK since 2009. In the last 15 years, BT has carried out about 400 innovation projects for 72 large multinational companies. BT belongs to the subset of PKCs made of private entities that have a business model and revenue streams based on facilitating OI processes. Within the Italian and European landscape, private knowledge intensive business operating as PKCs are not numerous. We chose BT for our case study because - since its inception - it has designed its organizational and business model to support clients in solving complex, system-level innovation problems. This specific focus has influenced, since the early years of BT, numerous choices such as personnel selection criteria, the problem-solving methodologies they use, the size and configuration of their solvers network, the presence and function of prototyping and testing laboratories. Over the years, BT has been considered by both governmental institutions and the academia as an exemplary case of OII. The company has been studied, both in the EU Business Innovation Observatory by Dervojeda et al. (2013) and by the Technical Committee of the Scottish Parliament in 2014, as well as in Danneels and Frattini's (2018) technology leverage study.

Following Siggelkow (2007), we selected BlueThink as a paradigmatic case that allows theory elaboration rather than statistical generalization. Access to the organization was facilitated by one author’s involvement in its management, which enabled exceptional depth of data access while preserving analytical independence in data collection and analysis. To mitigate potential bias, the author involved in BlueThink’s management was not involved in the interviews nor in the initial rounds of data coding and interpretation. Consistent with recent process research leveraging privileged organizational access while maintaining analytical rigor (e.g., Manelli et al., 2025), this study combines deep insider access with clear role separation in data collection and analysis, systematic triangulation, and iterative validation across authors to mitigate potential bias and enhance interpretive robustness.

3.2. Data collection and analysis

Most of our data was collected through in-person interviews conducted between November 2020 and November 2023 with managers and technical professionals working at BT in a variety of roles and seniority levels. In accordance with the theoretical saturation criterion, interviews were conducted until no more relevant information could be obtained through additional interviews (Corbin and Strauss, 2014). The semi-structured interview guide was divided into three main parts:

(i) The firm's approach, business model, organizational structure, roles, skills and capabilities, and activities performed with seekers and solvers.

(ii) The problems/projects that the firm usually undertakes, delving into practical and paradigmatic examples.

(iii) The structure of the projects, how BT empowers its clients' AC, and the processes, methodologies, and tools that support this process.

We conducted a total of 16 interviews with 12 employees and managers and contacted respondents with follow-up emails to obtain missing information and details. The use of a standardized and replicable interview protocol and the possibility to conduct a cross-case analysis by focusing on different innovation projects allowed us to increase the external validity of the study (Yin, 2009). Most of the interviews were conducted in the interviewees' native language (English or Italian). The quotes in Italian were translated into English, and the authors were asked to validate the translation.

Furthermore, to enhance the robustness of the collected evidence, we triangulated BT’s perspective with that of other external subjects involved in the innovation projects, namely seekers and solvers. We collected complementary evidence from both seekers and solvers involved in the two focal projects, including project documentation, email exchanges, and validation meetings, which allowed us to corroborate BT’s accounts of key decisions and outcomes.

To maintain impartiality, the interviews were analyzed anonymously by at least two authors in three stages: reading, coding, and interpretation, with the collected data summarized in a write-up after each stage (Saldana, 2015). Following Corbin and Strauss (2014), we used an open coding process to identify key sentences, sort them into first-order categories, and combine them into higher-level categories through axial coding to identify their relationship to the literature analyzed. Two authors independently coded the data and later discussed their findings, using investigator triangulation (Patton, 2002) to increase the credibility of the analysis. The resulting data structure, linking first-order concepts to second-order themes and aggregate dimensions, is presented in Figure 2 to support transparency and analytical rigor.

We also strengthened construct validity by incorporating multiple sources of evidence and asking respondents to review their cases (Yin, 2009). This allowed us to complete the write-ups and minimize the biases associated with retrospective interviews.

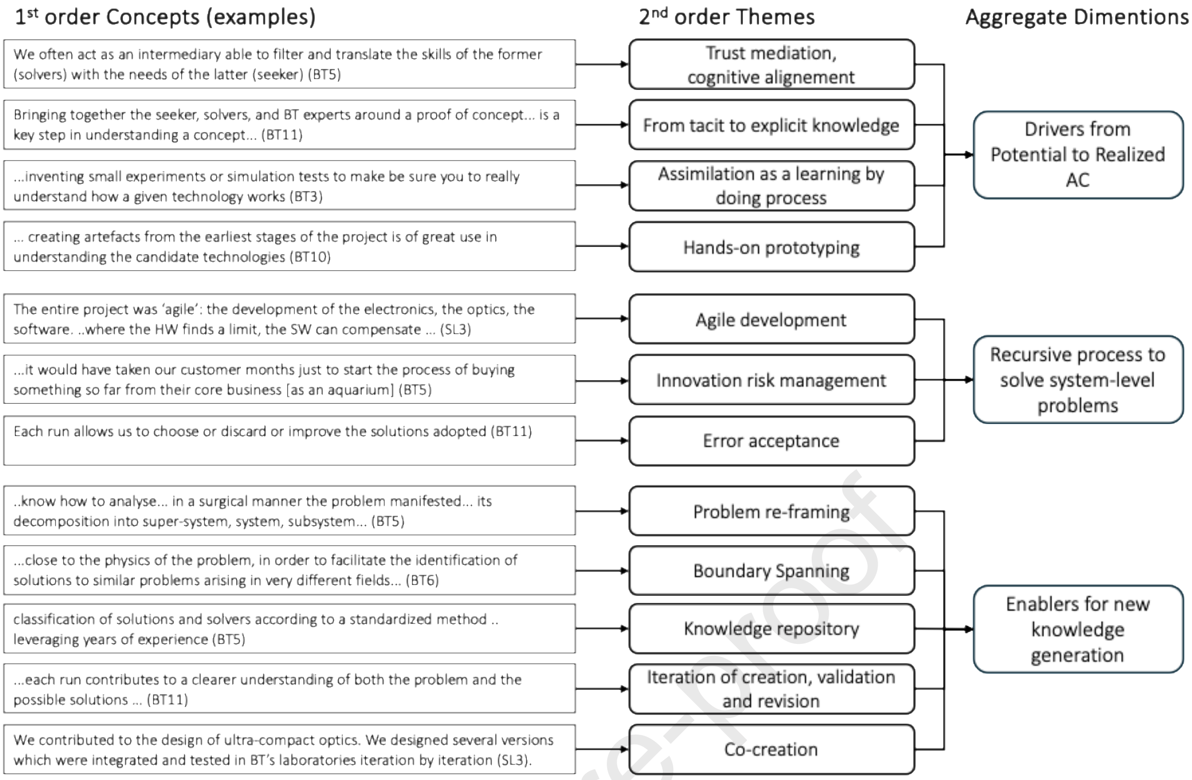


Figure 2 – Coding tree

Table 1 lists the key interviewees and their roles (their names have been anonymized for confidentiality reasons).

Table 1. Case-study interviewees

Interviewee ID	Type	Company	Role	Experience	Background	Education	Country
BT0	OII	BlueThink	Director	12	Mechanical engineering	MSC	UK
BT1	OII	BlueThink	Project Manager	10	Biomedical engineering	PhD	IT
BT2	OII	BlueThink	Project Manager	6	Electronic engineering	MSC	IT
BT3	OII	BlueThink	Business Development	> 20	Economics	MSC	IT
BT4	OII	BlueThink	Operations	3	Materials engineering	MSC	IT
BT5	OII	BlueThink	Project Manager	4	Mechanical engineering	MSC	IT
BT6	OII	BlueThink	Operations	2	Biomedical engineering	MSC	IT
BT7	OII	BlueThink	Project Manager	12	Materials engineering	PhD	IT
BT8	OII	BlueThink	Project Manager	6	Mechanical engineering	MSC	IT
BT9	OII	BlueThink	Operations	4	Computer Science engineering	MSC	UK
BT10	OII	BlueThink	Operations	4	Automation engineering	PhD	IT
BT11	OII	BlueThink	Chief Operating Officer	15	Materials engineering	PhD	IT
Sk1	Seeker	RWH	Project Manager	10	Mechatronics engineering	MSC	IT
Sk3	Seeker	OGI	Innovation manager	> 20	Mechanical engineering	MBA	IT
Sk4	Seeker	OGI	R&D Project Manager	15	Materials engineering	MSC	IT
Sl1	Solver	LaserTech	Director	> 20	Phisics	MSC	IT
Sl2	Solver	LaserTech	Technical Manager	10	Mechanical Engineering	MSC	IT
Sl3	Solver	OptoTech	Optical Designer	15	Optics	PhD	IT

We had access to a wealth of secondary data sources for this study, including BlueThink's capability assessment process and technical and soft skills training. This provided valuable insights into the competencies, attitudes, and practices developed by the firm’s internal staff, depending on their different roles and seniority levels. In addition, we were able to review internal training material on problem analysis, brainstorming, and other ideation processes, as well as creative problem-solving guides and tools for evaluating innovative concepts.

We also analyzed material from two different projects across all stages of their development, including photographs of brainstorming boards or emails between seekers, BT’s experts, and solvers. More than 100 GB of documents were analyzed for the two projects.

To analyze the rich body of collected data, we adopted the case analysis method (Pettigrew, 1990). Specifically, we focused, as primary unit of analysis, on the innovation process through which BT experts leverage creative problem-solving techniques to address system-level problems. The data collection and analysis proceeded through three fundamental steps.

Step 1 – In this phase, we developed an in-depth understanding of BT’s context by reviewing the extensive body of secondary material available. This review was instrumental in validating the choice of absorptive capacity as the theoretical lens for interpretation. We then conducted an initial round of interviews and analyzed all collected material to identify the practices adopted by BT personnel in supporting the seeker through the acquisition, assimilation, transformation, and exploitation phases of an externally sourced technology.

During this work, we recognized the centrality of the specific type of problems addressed, for which the seeker engages BlueThink. The problem analysis methodologies, creative problem-solving, agile solution development, and the approaches to involving both the seeker and the solvers are specifically designed to tackle system-level problems.

Step 2 – In this second step, we requested a series of clarifications from the interviewed actors, conducted additional interviews, and carried out an in-depth analysis of two projects to identify a workflow in which to frame the practices emerging from the interviews. To deepen our analysis, we developed a model of interaction between BT, the seeker, and the involved solvers, using the platform model (Trabucchi and Buganza, 2022) as an interpretative framework.

Step 3 – The analysis of the collected and classified material, structured into practices related to the different phases of the absorptive capacity (AC) process, allowed us to identify the cyclical recurrence of activities and processes that underpin the creation of new knowledge.

The analysis revealed a recurrent pattern of experimentation, testing, and redesign. To interpret this empirically observed cyclicality, we draw on the build–measure–learn logic of the lean cycle (Ries, 2011) as a sensitizing framework rather than a prescriptive model.

3.3. A focus on two innovation projects

To increase the robustness of our analysis, we adopted an embedded case study approach (Yin, 2009) to analyze two innovation projects conducted by BlueThink. In the following, we outline the BlueThink workflow and provide a detailed summary of one of the projects to illustrate the system-level innovation problems we focus on. Direct quotes from respondents are included to provide insight into the observed process. We then briefly describe the second project to contextualize the examples used in the findings section (Tables 2 to 5) to illustrate how a PKC support the development of its clients'AC.

3.3.1. BT workflow

BT's involvement often starts with a client requesting support in the development of a new product. Large multinationals with in-house R&D teams, engineering departments, and labs typically seek BT's expertise when they need specialized skills and solutions beyond their core competencies.

> *Think of a fitness shoe manufacturer… This firm will have in its R&D team specialists in polymeric materials, experts in numerical simulation of elastic materials, facilities … to*

> *prototype and characterize a rubber sole in a few hours. What happens if this company decides to develop a 'smart' shoe? The company will face the need to access expertise and technology in electronics, sensors, firmware, communication protocols, and machine learning for data interpretation. All this long before they can define what the problems are and where we can look for solutions* (BT2).

> *The company may not have a clear idea of the contours or features of the product… They may have an idea of what competitors are doing. Competitors, for example, might have developed a product that provides information about body weight distribution during exercise. The company, looking only at the competitive environment, may not ask itself whether it is possible to measure, for example, heart rate and oxygen saturation on the foot* (BT11).

This type of problem is what is referred to at BT and in the literature (Agogué et al., 2017; Pham et al., 2023) as system-level problem.

> *The problem often has more 'nuanced' boundaries, is expressed as a marketing wish or hidden in a generic performance improvement request* (BT11).

Firms turn to BT from a solving perspective (Pinarello et al., 2022) to design or improve a product that they do not have all the capabilities to develop internally. These are often complex problems that require the convergence and integration of very different skills and technologies.

> *When you face a complex problem, it is rare that a solver has "the solution", more likely its technology could be a part of the solution, like a piece of a puzzle. Then if you ask solver alpha if it can solve problem X, it will probably say no... while its technology could be a key element of the solution. Imagining the whole puzzle, is up to us and our collaboration with*

the customer (BT3)

Multinationals with R&D and engineering departments turn to BT to solve problems that often require them to search for solutions in knowledge domains far removed from their own. Rather than simply acquiring a technology, BT helps seekers in these situations by assimilating and transforming the knowledge and technology they do not possess.

Solvers on the other hands, have the opportunity to see their technologies applied in different contexts and thus expand their market.

When the state of the art is laser welding a few millimeters of steel, BT proposes that we develop a technology for welding thicknesses an order of magnitude greater for the oil & gas industry (SL1)

3.3.2. Project one: RWH

RobotWareHouse (RWH), a specialist in robotics for automated warehouses, approached BT to solve the problem of protecting the batteries of its pickup robots from the cold in refrigerated warehouses. This problem was reducing the average battery life by up to 20%.

Prior to scouting for battery thermal protection technologies. Using creative problem-solving techniques, the robot was reconceptualized into subsystems and all interactions with the battery pack were mapped. The analysis allowed to identify several technology bottlenecks.

For each technology bottleneck, industry sectors were identified where common problems could have led to the development of a solution, leveraging BT's expertise and project database. At this stage, a scouting exercise was undertaken to identify multiple enabling technologies for each solution strategy. BT worked with the seeker to generate innovative solutions through brainstorming sessions. These solutions often require the integration of multiple enabling technologies and, in some cases, the creation of missing pieces of the puzzle.

Supercapacitors, a technology used in light rail, sports cars, and drone applications, were selected for exploration among the many alternatives available.

RWH, which has no testing facilities, asked BT to conduct a field test by integrating supercapacitors into a robot. BT proposed an alternative approach, using its laboratory facilities to build a setup to rigorously test several critical aspects: performance at low temperatures, the ability to cope with a regime of acceleration/deceleration and changes of direction.

BT proposed placing the robot’s traction subsystem and a smaller battery pack (1/4 the size) inside a horizontal refrigerator in BT’s labs.

The setup was implemented at very low cost and in much less time than a full-scale system, avoiding interference problems typical of working in a live warehouse. The creation of a prototype, albeit basic and unfinished, for testing in BT’s labs brought the seeker, the BT experts, and the solvers together. The setup allowed them to explore the limitations of the technology in terms of functionality, performance, and integrability, which was critical to aligning their vision as they transitioned from this initial experiment to the subsequent solution design stage.

The co-design stage involved collaborating with other solvers and the development of ad-hoc solutions by BT, including the power management algorithm. This iterative process resulted in four different prototypes of the power unit and associated subsystems.

During the third validation and test run, a functional requirement emerged for the robot’s ‘mission profile’ that required the development of a hybrid power unit combining lithium batteries and supercapacitors.

This was a critical point for the project. The failure of some tests could have been perceived as a failure of the entire project, but the team’s practice of regularly revisiting and re-evaluating the solutions in each round of experimentation helped them see this redesign as a conscious configuration choice in the iterative process.

During product development, the team was able to run parallel activities, including freedom-to-operate, IP protection, cost quantification, and integrability assessments. These activities were followed by design-to-cost and design-to-manufacturing tasks in the later prototyping stages. As the engineering and prototyping efforts converged, not only was the technical problem ‘solved,’ but key economic, integration, and industrialization data were obtained to bring the solution to market.

The hybrid solution enabled a reduction in the cost of ownership of RWH robots, estimated at €6 million per year for each warehouse, and the same system architecture is now being used in several electric vehicles for industrial and consumer use.

3.3.3. Project two: OGI

The seeker, Oil&Gas Infrastructures (OGI), operates in the oil and gas sector and aimed to develop a short-range wireless communication device capable of operating at great depths underwater. The device would allow the instrumentation of a subsea structure to collect real-time data on its physical condition during operation, creating a digital twin of the infrastructure through the technology developed. The seeker had not yet decided on the specific technology to be used, but ruled out sonar as the typical frequencies used for communication in offshore oil and gas fields are often congested. BT supported OGI through all stages of the AC process.

Acquisition: The activity began with analyzing the problem to identify the various subsystems and the enabling technologies for each, resulting in the definition of a concept for an optical communications solution using laser emitters.

Assimilation: Benchmarking different laser emitter and receiver alternatives. Simple experiments generated ideas on how to control the system to ensure low power consumption and reliable data transmission.

Transformation: Through cyclic prototyping, testing and redesign, first the subsystems and then the integrated system were developed. Specific technologies and skills were drawn from solvers in different sectors (e.g., a solver specializing in hyperbaric chambers and hydrofoils was involved in designing the body and joints of the device). BT designed and prototyped all the subsystems required to integrate the device.

Exploitation: Support was provided for intellectual property protection, extensive field testing, and industrialization of the device.

The activities are described in detail in Tables 2 to 5 and were analyzed to derive the practices and tools used by BT in the different stages and the transition between potential and realized AC.

4. Findings

We present our findings using absorptive capacity as the primary analytical lens. Following Zahra and George (2002), we structure the evidence around four stages: acquisition, assimilation, transformation, and exploitation, and we map the role of BlueThink as a physical knowledge contributor across these stages.

We observed a recurrent pattern of experimentation, testing, and redesign in all the phases. We therefore use the build–measure–learn logic as a heuristic tool to make this cyclicality analytically visible.

4.1. Acquisition

In the acquisition stage, the focus is on identifying and mobilizing externally generated knowledge. In system-level problems, acquisition is not a mere knowledge search activity. It starts with problem reframing, through which the PKC and the seeker jointly redefine the problem space and translate it into technology needs that can be explored across distant domains.

4.1.1. Build: PKC and the seeker interact

Workshops and brainstorming sessions are conducted to redefine the problem, its scope, and the desired solution. The involvement of various stakeholders and PKC experts with multidisciplinary skills and experience helps to deconstruct the problem, identify the fundamental elements of the system and the interactions between the subsystems and the external environment. This allows isolating the elementary problems, or bottlenecks in BT jargon.

BlueThink supports seekers through structured problem reframing practices, aimed at decomposing the system, identifying key interactions, and isolating technological bottlenecks that guide subsequent search, through tools like TRIZ methodology (Al'tshuller, 1999; Ilevbare et al., 2013).

> *The kind of problems we face often require us to invent complex solutions, which leverage a sensor invented by one solver, a data processing algorithm created by a second solver, and perhaps control electronics designed by us* (BT11)

4.1.2. Build: PKC and the solvers interact

BT's boundary spanning process involves identifying the knowledge pools that need to be searched for the enabling technologies. By redefining the problem, BT's experts express a technology need in a language that is:

> *... close to the physics of the problem, in order to facilitate the identification of solutions to similar problems arising in very different fields and to identify the most appropriate solutions or approaches, irrespective of the starting sector* (BT6).

Table 2. The PKC's role in supporting the acquisition of external technology

Acquisition

	Specific Objective	Tools and Practices	Actors	Evidence from RWH	Evidence from OGI
Build	Develop a set of concepts that meet the seeker's need, identify the technologies to be acquired that will enable its realization.	• Brainstorming • Creative problem solving (design thinking) • Creative problem solving (TRIZ)	PKC Seeker	RWH, a specialist in robotics for automated warehouses, asks BlueThink (BT) to address the problem of protecting the batteries of pickup robots from the cold in refrigerated warehouses. (Learn) BT conducts a brainstorming session with RWH experts and BT engineers with multidisciplinary skills and experience in different industries, with two different objectives: to understand how to reframe the problem, and to identify industries facing the same problem. (Measure) In parallel, BT experts use creative problem-solving techniques to deconstruct the robot into subsystems and map the interactions of all these subsystems, including the battery pack. (Learn) The problem is reframed from "protecting pickup robot batteries from the cold" to "finding a solution to reduce the cost of pickup robot batteries". (Build) Numerous strategies to achieve the formulated goal are listed and discussed with the seeker. Scouting activities are conducted to identify multiple enabling technologies for each solution strategy. Solution concepts are generated. (Measure) The most promising concepts undergo a first validation through simple measurement and gap analysis with respect to the original application area of the enabling technologies. (Learn) A concept based on supercapacitors - an energy storage technology used in light rail systems – emerges as promising.	The seeker wants to develop a short-range wireless system to build a digital twin of a subsea structure. The seeker has no clear idea of which technology to use. (Learn) An analysis of the technical, scientific, and patent literature is conducted to identify possible solutions that originated in sectors far removed from oil and gas, for example, telecommunications. (Measure) In parallel, the problem is analyzed to understand implementation constraints, expected system performance, etc. (Build) Concepts based on different technologies are generated in collaboration with the seeker, and specific solvers are identified. (Measure) The most promising concepts are analyzed by identifying specific subsystems, their interactions, and performing simple measurements, for example, communication performance in water, energy consumption, etc. (Build) This analysis and the interaction with specific solvers allow refining the concept considered promising: an optical communication technology based on laser emitters. (Learn) An initial IP search shows there are no "freedom to operate" obstacles. (Measure) The analysis of the chosen concept reveals three main bottlenecks that need to be examined in depth: energy consumption, robustness to vibrations, and the performance of emitters and receiver in water. Energy consumption is verified by simple calculations based on the declared consumption of the emitters and the assumptions of the data transmission system. (Learn) The effect of vibrations and strategies to mitigate them can be addressed at this stage by analogy with other applications. Finally, different types of emitters and receivers are identified, many of which have never been tested for performance in water.
Measure	Deconstruct and analyze to understand the limits and potential of a concept and the technologies identified to realize it.	• Multiscale analysis (TRIZ) • Cause/effect analysis (TRIZ) • Thought experiments (design thinking) • Simple measurements • Gap analysis	PKC		
Learn	Analyze the problem, understand the state of the art of the technology and the IP constraints to guide the search for solutions.	• Scientific/technical literature • IP databases	PKC Solvers		

The BT team draws on multidisciplinary expertise to identify solutions through brainstorming sessions with specialists from a range of sectors and skills. This is complemented by a thorough review of the technical and scientific literature. The team then deepens and validates each hypothesis by bringing in specific solvers. This approach builds on the interdisciplinary nature of the team and BT’s culture of lateral thinking.

> *…the interdisciplinary nature of the team and the use of experience developed in the past has often made it possible to quickly identify a large number of technologies used in different sectors* (BT1)

Over time, BT has developed resources to improve the effectiveness of boundary spanning processes. Using databases, knowledge from past projects has been made explicit and formalized. One useful tool is the solver database:

> *... classification of solutions and solvers according to a standardized method using project templates that have been updated over the time, leveraging years of experience* (BT5)

BT systematically accesses the scientific, technical, and patent literature to investigate distant research domains.

4.1.3. Measure: PKC, the seeker, and the solvers interact

The PKC works closely with the solvers to gather critical information and verify the initial premises and assumptions. Concept validation includes thought experiments, simple engineering measurements, and gap assessments:

> *… providing comparative evaluation on similarities and possible criticalities related to the technology transfer is most of the time extremely useful* (BT5)

Measurement activities serve the purpose to validate assumptions and identify early gaps that reshape the search direction and the configuration of candidate solution concepts.

4.1.4. Learn: PKC and the seeker interact

The information gathered from these measurement activities is then used to redefine solution concepts in an iterative flow of critical design and validation.

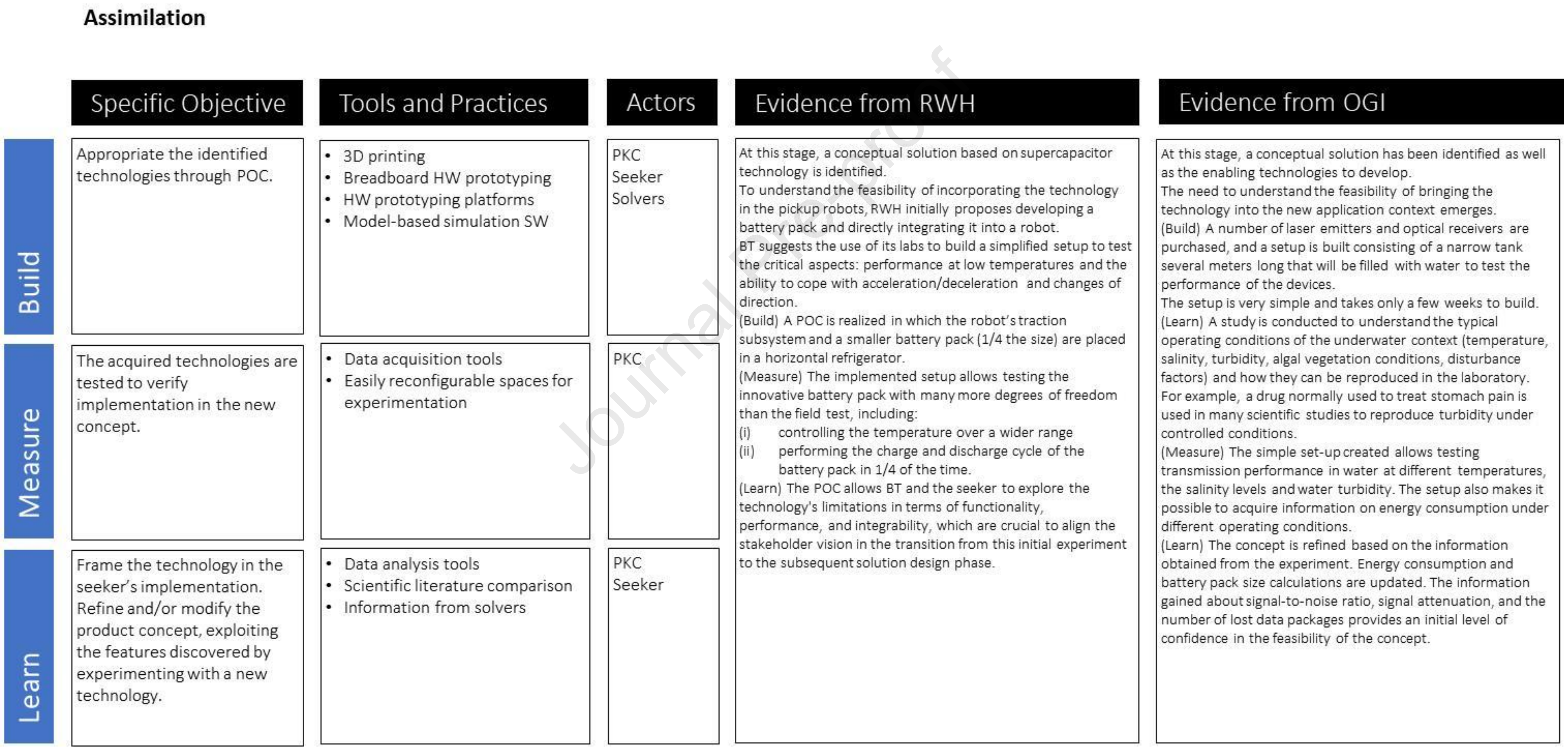
The acquisition process (Figure 3a) starts from the seeker and activates interactions with selected solvers. The PKC structures this interaction by mapping and reframing the seeker's problem toward its external network, already shaping preliminary solution concepts internally. In response, solvers provide technological inputs that are iteratively recombined within the PKC. This bidirectional and recursive exchange enables progressive problem reframing and identification of viable solution paths.

Figure 3a. Acquisition process

4.2. Assimilation

In the assimilation stage, the focus shifts from search to understanding and internalization. The integration of external technologies often requires overcoming knowledge, cultural, and organizational barriers.

Table 3. The PKC's role in supporting the assimilation of external technology



Assimilation

	Specific Objective	Tools and Practices	Actors	Evidence from RWH	Evidence from OGI
Build	Appropriate the identified technologies through POC.	• 3D printing • Breadboard HW prototyping • HW prototyping platforms • Model-based simulation SW	PKC Seeker Solvers	At this stage, a conceptual solution based on supercapacitor technology is identified. To understand the feasibility of incorporating the technology in the pickup robots, RWH initially proposes developing a battery pack and directly integrating it into a robot. BT suggests the use of its labs to build a simplified setup to test the critical aspects: performance at low temperatures and the ability to cope with acceleration/deceleration and changes of direction. (Build) A POC is realized in which the robot's traction subsystem and a smaller battery pack (1/4 the size) are placed in a horizontal refrigerator. (Measure) The implemented setup allows testing the innovative battery pack with many more degrees of freedom than the field test, including: (i) controlling the temperature over a wider range (ii) performing the charge and discharge cycle of the battery pack in 1/4 of the time. (Learn) The POC allows BT and the seeker to explore the technology's limitations in terms of functionality, performance, and integrability, which are crucial to align the stakeholder vision in the transition from this initial experiment to the subsequent solution design phase.	At this stage, a conceptual solution has been identified as well as the enabling technologies to develop. The need to understand the feasibility of bringing the technology into the new application context emerges. (Build) A number of laser emitters and optical receivers are purchased, and a setup is built consisting of a narrow tank several meters long that will be filled with water to test the performance of the devices. The setup is very simple and takes only a few weeks to build. (Learn) A study is conducted to understand the typical operating conditions of the underwater context (temperature, salinity, turbidity, algal vegetation conditions, disturbance factors) and how they can be reproduced in the laboratory. For example, a drug normally used to treat stomach pain is used in many scientific studies to reproduce turbidity under controlled conditions. (Measure) The simple set-up created allows testing transmission performance in water at different temperatures, the salinity levels and water turbidity. The setup also makes it possible to acquire information on energy consumption under different operating conditions. (Learn) The concept is refined based on the information obtained from the experiment. Energy consumption and battery pack size calculations are updated. The information gained about signal-to-noise ratio, signal attenuation, and the number of lost data packages provides an initial level of confidence in the feasibility of the concept.
Measure	The acquired technologies are tested to verify implementation in the new concept.	• Data acquisition tools • Easily reconfigurable spaces for experimentation	PKC		
Learn	Frame the technology in the seeker's implementation. Refine and/or modify the product concept, exploiting the features discovered by experimenting with a new technology.	• Data analysis tools • Scientific literature comparison • Information from solvers	PKC Seeker		

4.2.1. Build: PKC, the seeker, and the solvers interact

With its laboratory structure, BT acts as a platform that enables the seeker to assimilate through experimentation. Understanding a technology is seen not only as a process based on theoretical skills and knowledge, but also an empirical process of successive experimentation.

> *... inventing small experiments or simulation tests to be sure to really understand how a given technology works* (BT3)

BT uses 3D printers, simplified designs, virtual validation tools, simulation, design model-based tools, and hardware platforms designed for prototyping, such as FPGAs or Arduino, to conduct simple and informative experiments.

4.2.2. Measure: PKC is the main actor

This path may involve rejecting options, identifying early criticalities, and generating new ideas through knowledge creation with the seeker, PKC experts, and multiple solvers.

The process of building proof of concepts (PoCs), measuring performance, and redefining concepts can be done in parallel for alternative technologies.

4.2.3. Learn: PKC, the seeker, and the solvers interact

Assimilation as an empirical process involves the seeker, who is often invited to participate in the experiments and tests. In a sense, the physicality of the intermediary allows for shared empirical awareness (Schiuma and Santarsiero, 2023).

> *Bringing together the seeker, solvers, and BT experts around a proof of concept - however rough it may be - is a key step in understanding a concept, looking at it with a critical eye, and generating new ideas* (BT11)

> In BT’s labs, solvers share information and lend their expertise as active participants in creating PoCs. Solvers’ tacit knowledge emerges during experimentation, is shared and became then explicit into specific design choices.

> *For example, a solver with deep experience in … lasers enabled a better understanding of the hidden problems in integrating a power laser source into a vessel* (BT1)

From the seeker’s perspective, experiencing a new technology is “projecting” it into a new purpose.

The value of certain solutions sometimes emerged while we were in the lab. For example, BT had installed a camera inside the device to show how the prototype was working. Soon we realized that the cam could be used to attest to the quality of the final result. (SK2)

At this stage, BT reduces cognitive and domain barriers between the seeker and the solvers by providing translational and integrative expertise. In addition, the seeker and solver may not have all the necessary skills, and the BT team supplements these or activates an additional solver. In particular, BT has a diverse pool of internal skills and cultivates interdisciplinarity and lateral thinking as core skills through involvement in projects in different industries.

> *This (interdisciplinarity) is reinforced by the fact that we are involved in projects from very different fields, so studying new topics is the order of the day and constitutes a kind of training* (BT1)

> *We often act as an intermediary able to filter and translate the skills of the former (solvers) with the needs of the latter (seeker)* (BT5)

BT facilitates a shared interaction space that supports both dialogue and trust formation. In the assimilation process (Figure 3b), technological knowledge from different solvers flows to the seeker through the PKC's physical infrastructure. This interaction fosters cognitive alignment and supports learning-by-doing, enabling stakeholders to test, reinterpret, and refine solution concepts. Through iterative feedback loops, explicit and tacit knowledge are progressively internalized by the seeker in a cyclical process of recombination.

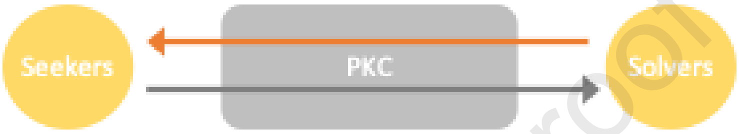


Figure 3b. Assimilation process

4.3. Transformation

In the transformation stage, the emphasis is on recombining existing and newly assimilated knowledge into internally consistent solution architectures. In BT, the development of a product idea that relies on transformation capabilities follows a recursive process that involves agile development for both the software and hardware components of the project in parallel. In this context, BT offers a methodical approach to configuring the project in a run-by-run manner. From the interviews emerged the idea of transformation as a recursive process, divided and managed in development iterations. The reference is to agile development as an:

> *Each run contributes to a clearer understanding of both the problem and the possible solutions* (BT11).
>
> *After each test, we understood how to modify the prototype. Then we moved on to field testing, and the comparison with the operators led to other ideas and the need for further modifications (SK2).*

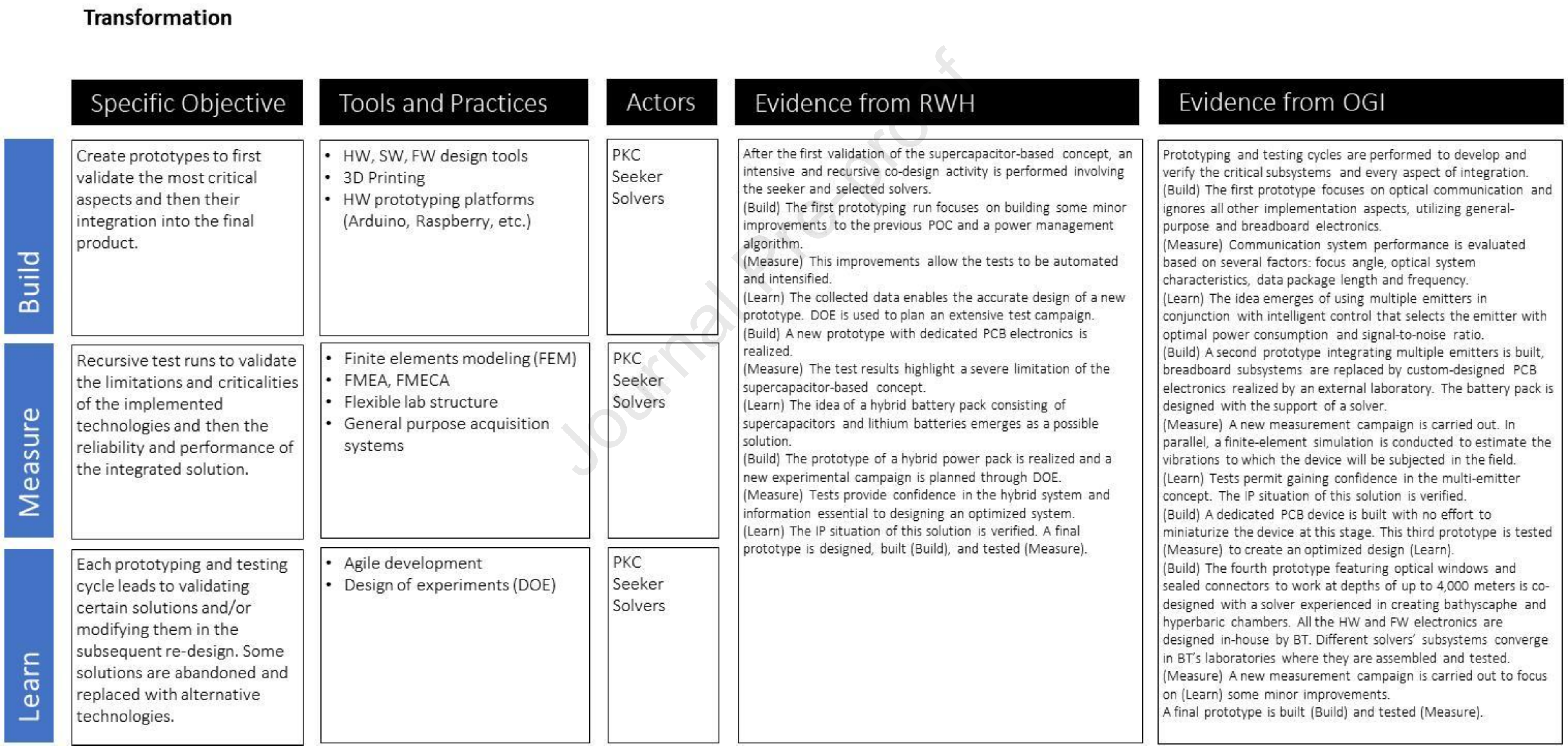
Physical infrastructure is needed, including laboratories and equipment for prototyping and testing, which is a characteristic of physical intermediaries. This approach implies a high level of acceptance of failure as part of the innovation process (Ries, 2011).

4.3.1. Build: PKC and solvers interact

BT typically assists the seeker in developing an innovative concept through successive prototyping and testing, extending this agile approach not only to software development but also to the realization of hardware components.

> *Typically our clients have teams of specialists and well-equipped laboratories but they are struggling to simplify a problem and to break down the product development process into runs of simple activities to test the main critical aspects of a concept in a time and cost-efficient way (*BT11).

Table 4. The PKC’s role in supporting the transformation of external technology.



Transformation

	Specific Objective	Tools and Practices	Actors	Evidence from RWH	Evidence from OGI
Build	Create prototypes to first validate the most critical aspects and then their integration into the final product.	• HW, SW, FW design tools • 3D Printing • HW prototyping platforms (Arduino, Raspberry, etc.)	PKC Seeker Solvers	After the first validation of the supercapacitor-based concept, an intensive and recursive co-design activity is performed involving the seeker and selected solvers. (Build) The first prototyping run focuses on building some minor improvements to the previous POC and a power management algorithm. (Measure) This improvements allow the tests to be automated and intensified. (Learn) The collected data enables the accurate design of a new prototype. DOE is used to plan an extensive test campaign. (Build) A new prototype with dedicated PCB electronics is realized. (Measure) The test results highlight a severe limitation of the supercapacitor-based concept. (Learn) The idea of a hybrid battery pack consisting of supercapacitors and lithium batteries emerges as a possible solution. (Build) The prototype of a hybrid power pack is realized and a new experimental campaign is planned through DOE. (Measure) Tests provide confidence in the hybrid system and information essential to designing an optimized system. (Learn) The IP situation of this solution is verified. A final prototype is designed, built (Build), and tested (Measure).	Prototyping and testing cycles are performed to develop and verify the critical subsystems and every aspect of integration. (Build) The first prototype focuses on optical communication and ignores all other implementation aspects, utilizing general-purpose and breadboard electronics. (Measure) Communication system performance is evaluated based on several factors: focus angle, optical system characteristics, data package length and frequency. (Learn) The idea emerges of using multiple emitters in conjunction with intelligent control that selects the emitter with optimal power consumption and signal-to-noise ratio. (Build) A second prototype integrating multiple emitters is built, breadboard subsystems are replaced by custom-designed PCB electronics realized by an external laboratory. The battery pack is designed with the support of a solver. (Measure) A new measurement campaign is carried out. In parallel, a finite-element simulation is conducted to estimate the vibrations to which the device will be subjected in the field. (Learn) Tests permit gaining confidence in the multi-emitter concept. The IP situation of this solution is verified. (Build) A dedicated PCB device is built with no effort to miniaturize the device at this stage. This third prototype is tested (Measure) to create an optimized design (Learn). (Build) The fourth prototype featuring optical windows and sealed connectors to work at depths of up to 4,000 meters is co-designed with a solver experienced in creating bathyscaphe and hyperbaric chambers. All the HW and FW electronics are designed in-house by BT. Different solvers’ subsystems converge in BT’s laboratories where they are assembled and tested. (Measure) A new measurement campaign is carried out to focus on (Learn) some minor improvements. A final prototype is built (Build) and tested (Measure).
Measure	Recursive test runs to validate the limitations and criticalities of the implemented technologies and then the reliability and performance of the integrated solution.	• Finite elements modeling (FEM) • FMEA, FMECA • Flexible lab structure • General purpose acquisition systems	PKC Seeker Solvers		
Learn	Each prototyping and testing cycle leads to validating certain solutions and/or modifying them in the subsequent re-design. Some solutions are abandoned and replaced with alternative technologies.	• Agile development • Design of experiments (DOE)	PKC Seeker Solvers		

In addition, PKC procedures and organizational forms are often more agile in adapting to different needs.

> *When we had to test a subsea communication system, we had a 6-meter long aquarium built, used it for a few weeks and then dismantled ... it would have taken our customer months just to start the process of buying something so far from their core business* (BT5) as an aquarium.

The first stage of development may involve the creation of basic prototypes to verify aspects critical to the success of the project. This stage is used to select the most promising options when evaluating multiple technology alternatives simultaneously. Through subsequent iterations, the design progresses to a fully functional prototype and ultimately a pre-industrialization prototype.

4.3.2. Measure: *BT is the main actor*

The creation of an innovative solution often results

in two parallel projects: the design of the solution and the setup to test it.

The test also required a multidisciplinary approach. For example, to verify the function of laser communication in turbid water, they built an aquarium and used a protocol for clouding the water that was developed by NASA (SK3).

4.3.3. Learn: PKC and the seeker interact

Information gained from the experimentation is then used to redefine the concept or may lead to abandoning one solution in favor of another.

BT actively engages in knowledge completion. Solving system-level problems may require combining the expertise and technologies of different solvers and for BT to conceive some of the system's components. If the skills and technologies of the solvers prove insufficient, the

PKC must draw on its internal resources to ensure a seamless development process.

> *We developed a device with BT to collect and transmit data subsea. To do this, BT converged in its laboratories technologies used in the construction of hyperbaric Chambers, laser communication solutions, and a series of other ideas that BT then developed itself (SK3).*

The availability of design and simulation tools and physical assets such as laboratories play a critical role in the transition from potential to realized AC. Working through the stages of developing an innovative product with the client, discussing goals and agreed-upon assumptions or simplifications helps build the seeker's transformation ability ~~to transform~~.

In the transformation stage (Figure 3c), a cyclical co-creation process unfolds among the seeker, solvers, and PKC experts. The PKC enables knowledge mobility and recombination by mobilizing its physical infrastructures and intangible resources, including laboratories, interaction spaces, multidisciplinary expertise, and relational trust across actors.

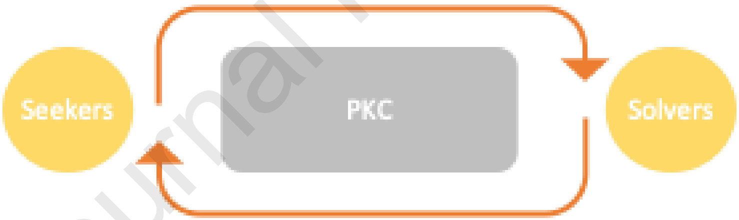
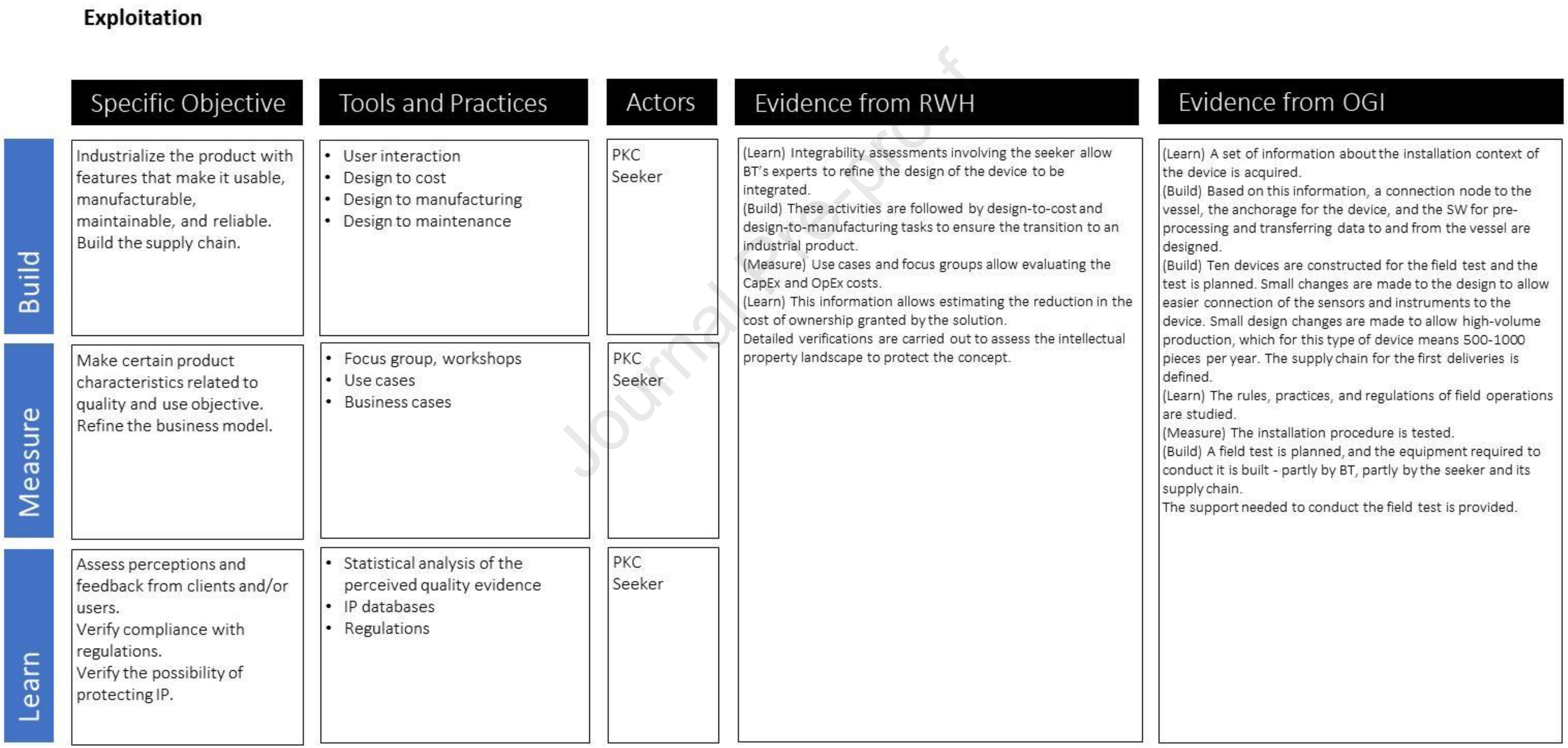


Figure 3c. Transformation process

4.4. Exploitation

In the exploitation stage, validated concepts are translated into industrialized and market-ready solutions. We analyze how validated concepts are progressively configured into market-ready solutions hereafter.

Table 5. The PKC's role in supporting exploitation of an external technology



Exploitation

	Specific Objective	Tools and Practices	Actors	Evidence from RWH	Evidence from OGI
Build	Industrialize the product with features that make it usable, manufacturable, maintainable, and reliable. Build the supply chain.	• User interaction • Design to cost • Design to manufacturing • Design to maintenance	PKC Seeker	(Learn) Integrability assessments involving the seeker allow BT's experts to refine the design of the device to be integrated. (Build) These activities are followed by design-to-cost and design-to-manufacturing tasks to ensure the transition to an industrial product. (Measure) Use cases and focus groups allow evaluating the CapEx and OpEx costs. (Learn) This information allows estimating the reduction in the cost of ownership granted by the solution. Detailed verifications are carried out to assess the intellectual property landscape to protect the concept.	(Learn) A set of information about the installation context of the device is acquired. (Build) Based on this information, a connection node to the vessel, the anchorage for the device, and the SW for pre-processing and transferring data to and from the vessel are designed. (Build) Ten devices are constructed for the field test and the test is planned. Small changes are made to the design to allow easier connection of the sensors and instruments to the device. Small design changes are made to allow high-volume production, which for this type of device means 500-1000 pieces per year. The supply chain for the first deliveries is defined. (Learn) The rules, practices, and regulations of field operations are studied. (Measure) The installation procedure is tested. (Build) A field test is planned, and the equipment required to conduct it is built - partly by BT, partly by the seeker and its supply chain. The support needed to conduct the field test is provided.
Measure	Make certain product characteristics related to quality and use objective. Refine the business model.	• Focus group, workshops • Use cases • Business cases	PKC Seeker		
Learn	Assess perceptions and feedback from clients and/or users. Verify compliance with regulations. Verify the possibility of protecting IP.	• Statistical analysis of the perceived quality evidence • IP databases • Regulations	PKC Seeker		

4.4.1. Build: *PKC and the seeker co-create*

BT collaborates with the seeker to shape the product, resulting in design by criticism (Verganti, 2016), a powerful tool for defining the key features and usability of the product. Supporting the positioning of a new product in the market may include activities such as market analysis, regulatory, competitor, and intellectual property (IP) assessments.

> *It was also necessary to integrate other types of information: cost analysis, patent research, risk analysis and safety issues... Typical processes can be market analysis, competitor analysis, supplier selection, prototyping* (BT2)

Leveraging its solvers network, BT helps the seeker build a supply chain to industrialize the product.

4.4.2. Measure: PKC and the seeker co-create

Product positioning, business cases, and trends are the ways in which the product is measured prior to launch.

> *Therefore, a literature review of the architecture and construction industry was conducted to understand how the different technologies are evaluated by end users and* how these technologies are evaluated by end users and how they are implemented in practice (BT2)

> *Leveraging our knowledge repository and a search for information guided by the KPIs defined at the beginning of the project, the BlueThink team was to provide the client with a market study with comparative tables and graphs that made it easy to position the product* (BT15).

User testing activities to verify functionality, usability, or to gauge the appeal of the product to a particular customer group can be organized by the seeker with the support of BT, or by BT itself.

4.4.3. Learn: PKC and the seeker co-create

The ideas and information gathered from the usability, market context, IP framework, and regulatory assessments are incorporated into the industrialization design.

> *Systematizing the information acquired, consolidating and stratifying the body of knowledge. Progressively raising the point of observation of the outside world* (BT4)

At this stage, the design-to-cost and design-to-production tools and methodologies provide valuable support for the creation of the industrialization design.

In the exploitation stage (Figure 3d), the PKC and the seeker co-develop a market-ready solution, with the PKC providing complementary capabilities that support industrialization and market positioning.

Figure 3d. Exploitation process

5. Discussion

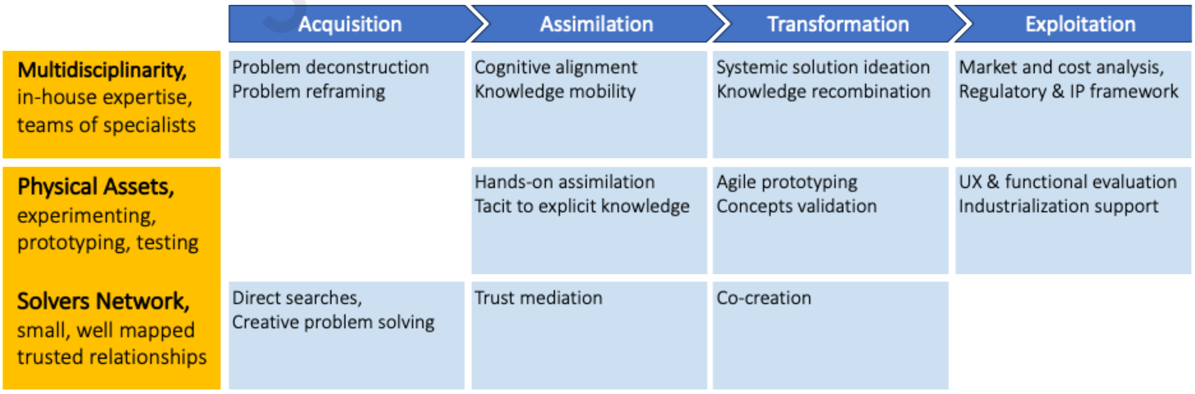
5.1. Absorptive capacity and the role of PKCs

Our findings suggest that PKCs cannot be adequately understood simply as knowledge transaction facilitators. Unlike VKBs, whose primary role is to enable matching between seekers and solvers (Tauscher and Laudien, 2018), PKCs appear to actively orchestrate the knowledge creation process to the benefit of the seeker (Trabucchi et al., 2022). This orchestration involves problem reframing, coordination of multiple solvers, iterative experimentation, and the integration of partial solutions into coherent system-level configurations. This shows how the platform provider (the PKC) is actively building value in creating the match, but also in performing high-value-added activities, managing a meta organization where value is coming from the interactions among all the parties involved (Kretschmer et al., 2022).

This shift from transaction to orchestration highlights an important difference in how certain physical intermediaries can operate within open innovation processes.. Rather than reducing search or transaction costs, PKCs create value by shaping how knowledge is generated, recombined, and validated over time, as we highlighted by using the AC lens (Zahra and George, 2002).

The BlueThink case suggests that PKCs can play a critical role in innovation ecosystems, particularly in radical and complex innovation projects addressing system-level problems. PKCs act as a two-sided platform that connects seekers with solvers, contributing to the creation of new knowledge. Table 7 provides an overview of the contribution of PKCs to the generation of new knowledge across the different stages of the AC process and their characteristics as intermediaries.

Table 7. The contribution of PKCs to knowledge creation in open innovation processes



	Acquisition	Assimilation	Transformation	Exploitation
Multidisciplinarity, in-house expertise, teams of specialists	Problem deconstruction Problem reframing	Cognitive alignment Knowledge mobility	Systemic solution ideation Knowledge recombination	Market and cost analysis, Regulatory & IP framework
Physical Assets, experimenting, prototyping, testing		Hands-on assimilation Tacit to explicit knowledge	Agile prototyping Concepts validation	UX & functional evaluation Industrialization support
Solvers Network, small, well mapped trusted relationships	Direct searches, Creative problem solving	Trust mediation	Co-creation	

By examining PKCs through the lens of absorptive capacity, this study extends existing interpretations of the AC construct within the context of system-level innovation mediated by physical platform intermediaries in three ways. First, absorptive capacity emerges as a process rather than a static firm-level capability. Second, it is found to unfold through recursive cycles of experimentation and learning rather than through a linear sequence of path-dependent stages. While absorptive capacity provides the macro-structure of acquisition, assimilation, transformation, and exploitation, the build–measure–learn cycle allows us to observe the micro-dynamics unfolding within each stage. In particular, it makes visible the iterative experimentation, early validation, and rapid reconfiguration processes that characterize platform-orchestrated innovation, showing the recursive value creation mechanism that is typical of a platform (Trabucchi et al., 2022), but made more evident and complex by the physical dimension. Without this sensitizing device, the recursive and practice-based nature of absorptive capacity in system-level contexts would remain partially obscured behind its stage-based abstraction. Third, parts of this process are enacted outside firm boundaries and temporarily orchestrated by an external actor, i.e. the PKC.

In the context analyzed, the locus of absorptive capacity appears to become distributed across the platform that interconnects the PKC, the seeker, and the solvers involved. While our findings highlight the enabling role of PKCs, strong orchestration may also entail trade-offs. In particular, when key phases of problem reframing, experimentation, and knowledge recombination are heavily mediated by the PKC, seekers may risk developing forms of dependence on the intermediary's capabilities, coherently with the shared value creation process typical of platform mechanisms (Trabucchi et al., 2020). Moreover, learning outcomes may remain uneven if parts of the absorptive capacity process are scaffolded externally rather than fully internalized within the seeker organization. These dynamics do not undermine the value of PKCs but suggest that their long-term impact depends on how effectively knowledge and routines are re-embedded within the seeker firm through effective learning processes. This study outlines the anatomy of the different components and stages of AC. The first stage, acquisition, involves identifying and acquiring external knowledge that is useful for innovation. VKBs typically use strategies such as framing and boundary spanning, while PKCs deconstruct system-level problems using their internal skills and capabilities, addressing problem complexity and ill-definition through creative problem solving and design thinking (Dell'Era et al., 2020). The literature recognizes that searching across diverse knowledge domains is associated with the generation of radical innovation (Ahuja and Katila, 2004; Miller et al., 2007). Unlike VKBs, which favor quantity through extensive web portals to engage solvers, PKCs focus on the quality of their network. Our findings suggest that, through smaller, well-mapped solver networks, PKCs may enable deeper knowledge recombination, which is essential for solving complex problems (Trabucchi et al., 2021).

The second stage of AC, assimilation, involves understanding and processing the acquired knowledge to make it usable but the innovation seeker. PKCs, with their multidisciplinary in-house expertise, play a critical role in this stage by providing a physical and cultural interface that fosters frequent high-quality external exchanges (Caccamo et al., 2023; Ma and Zhu, 2025). Through their laboratories, they engage both the seeker and the solvers in a learning-by-doing assimilation process. This is fundamental to understand the focal technology and its boundaries, and finally to imagine new uses or possible integrations for solving system-level problems. Managing a portfolio of options with a plurality of actors favors the level of innovation of the solutions generated. By establishing trusting relationships, they facilitate a cultural intersection that enhances dialogue and the co-creation processes, with PKCs often acting as trust intermediaries between seekers and solvers, thereby enriching the assimilation process (Billington and Davidson, 2013; Ert et al., 2016).

In the transformation stage of AC, assimilated knowledge is integrated into an organic concept, a process that is central to the creation of new knowledge through the adaptation and integration of technologies (Elmquist et al., 2016). This process involves recombining knowledge from different solvers and creating the "missing pieces" of the solution. The physical infrastructure of the PKC is essential at this stage to engage both seekers and solvers in a recursive, agile process where problems are analyzed, solutions are co-created and then critically revised in each run. The BT case illustrates how PKCs serve as knowledge repositories that complement the knowledge of seekers and solvers (Spithoven et al., 2011).

In the exploitation stage, acquired, assimilated, and transformed knowledge is used to create new products. PKCs actively participate in the co-creation process by providing a blend of technical expertise and strategic guidance. This support is critical to defining innovative products that are aligned with market trends, IP landscapes, and regulatory requirements. The role of PKCs at this stage underscores their impact on the seeker's ability to exploit knowledge and ensure that the integration of new technologies translates into a competitive advantage (Howells, 2006; Zahra and George, 2002).

Throughout the stages of the AC concept, PKCs and VKBs exhibit different approaches to managing knowledge. PKCs are characterized by their direct involvement in knowledge creation, leveraging internal competencies, and a deeper, higher quality solver network to foster deeper knowledge recombination, a critical aspect of innovation. This contrasts with the emphasis on knowledge transactions of VKBs, suggesting a fundamental difference in how these intermediaries contribute to seekers' innovation journey.

5.2. A platform-based, cyclical, revised process for AC enabled by PKCs

In the previous section, we discussed how PKCs differ from VKBs in supporting OI processes along the different stages of the AC concept. Now, we examine the interconnected system to which the PKC belong, specifically the multi-stakeholder platform orchestrated by PKCs that connects seekers and solvers (Trabucchi and Buganza, 2022).

A key insight of this study concerns the role of physicality in platform-mediated knowledge creation, which expands the nascent literature on the physical dimension of platforms (Perez Mengual et al., 2023). Laboratories, prototypes, and experimental setups are not merely operational resources. They function as boundary objects that enable shared understanding, accelerate cognitive alignment, and support trust-building among heterogeneous actors.

Through hands-on experimentation and learning-by-doing processes, PKCs enable the transfer and recombination of both explicit and tacit knowledge. This physical dimension helps explain why PKCs are particularly effective in addressing ill-defined and system-level problems, where knowledge cannot be fully specified ex ante.

In presenting our findings, we have used a platform model to represent the key knowledge flows that occur in the four stages, as summarized in Fig.1 below. We now review and relate these findings to the platform literature.

The acquisition stage starts with the PKC, which transfers knowledge about the seeker's problem to solvers (orange arrow). Similarly, in the assimilation stage, the PKC maps knowledge about the solver's solution to the seeker. This brief description is highly consistent with the traditional view of two-sided transaction platforms as matchmakers (Parker et al., 2017), which base their main value proposition on the opportunity to reduce market frictions and help actors find each other (Evans and Schmalensee, 2016). This clearly speaks to the nature of VKBs, which focus their main value proposition on helping seekers find appropriate solvers (Verona et al., 2006). In this case, the VKB enables value creation as a cooperative phenomenon between the seeker and the solver. Consequently, the potential creation of new knowledge occurs through the cooperation between the seeker and the solver; the capabilities, competencies, and systemic overview necessary to generate a systemic solution eventually reside with the seeker (Figure 4). In a way, with VKBs, the platform role they perform ends with the matchmaking, while the remaining AC phases exist only among the seekers and the solver(s). This is not the case of PKCs, which continue to orchestrate the overall value creation process till the very last phase.

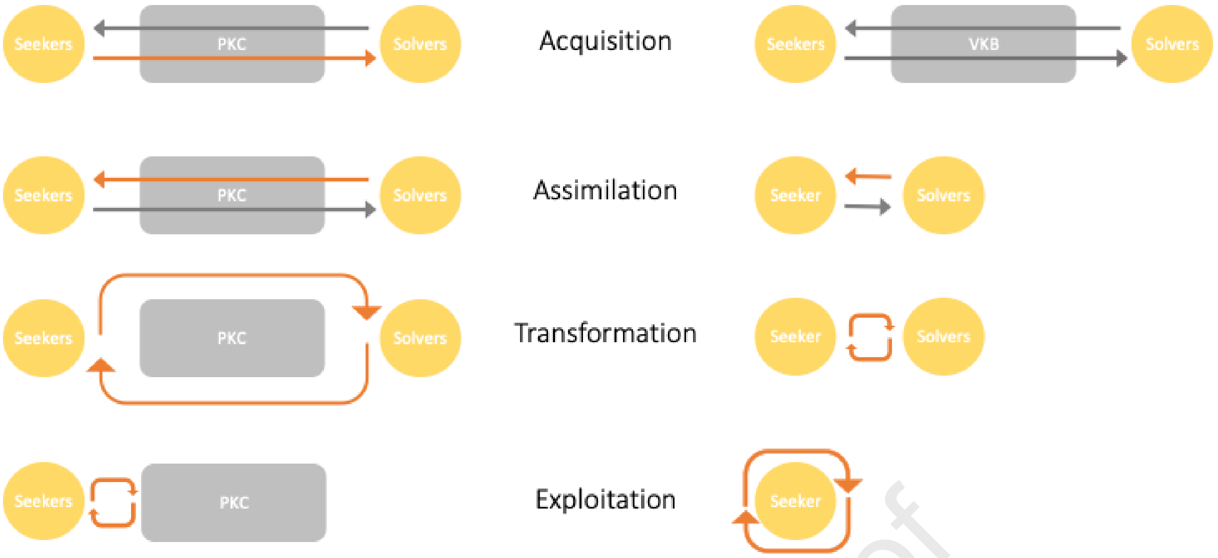


Figure 4. PKCs as platforms in comparison to VKBs

Nevertheless, the findings from our analysis of the BT case are consistent with more recent developments in the platform literature pointing out that the platform provider (the PKC in this case) plays an active role in the matching process and in managing the overall relationship between the two sides (Trabucchi et al., 2022). In this case, the physical nature of the PKC (it is not a purely digital platform but promotes direct, real interaction between all stakeholders) makes this element even more relevant.

In these first two stages, the PKC goes beyond facilitating communication and interaction between the seeker and the solver(s) and manage a cyclical agile process to propose ideas or technologies (build), assesses feasibility through activities it performs in the first person (measure), and thus defines how to proceed (learn). This allows PKCs to emerge as platform orchestrators (Jacobides et al., 2018), managing the flow of value and mobilizing the relationships that take place on and through the platform.

The transformation stage uses the same mechanisms, even seamlessly. Once the solver(s) are clearly on board, the PKC begins a continuous interaction with both actors to co-create new knowledge. In the BlueThink case, much of the knowledge recombination required to solve the system-level problem occurred within the boundaries of the PKC. In the BlueThink case, the capabilities, competencies, and overall vision required to envisage a systemic solution were largely concentrated within the PKC. This is consistent with the value creation dynamics of platforms, where all sides literally create value for all others (Trabucchi et al., 2021). At the same time, this reiterates the orchestration role of PKCs, which must manage an iterative agile process to maintain continuous alignment between the parties while transforming knowledge into the final solution (Bäcklander, 2019).

In the last stage, exploitation continues with the iterative loop to complete the innovation project, but sees a smaller set of actors on board, limiting the interaction between the PKC and the seeker. The last two steps illustrate the central role that the PKC played in the knowledge creation process, supporting the seeker until the very end of the innovation process, which differs significantly from the pure matchmaking proposed as the main role of VKBs (Verona et al., 2006).

The findings of this study should be interpreted within specific boundary conditions. The identified mechanisms are most likely applicable to project-based, engineering-intensive PKCs characterized by in-house laboratories, multidisciplinary teams, and long-term relational networks. Different configurations of physical intermediaries, such as industry associations with limited internal technical depth, may display different orchestration dynamics. Morevoer, the observed mechanisms are most likely to apply to innovation problems characterized by high uncertainty, interdependence among subsystems, and the need for iterative experimentation, which clearly distinguishes the contribution of VKBs from that offered by PKCs. In contrast, well-defined and modular problems may still be efficiently addressed through VKBs and transaction-oriented intermediaries (Verona et al., 2006).

To conclude, beyond firm-level innovation outcomes, PKCs may be understood as meso-level infrastructures that support collective learning across organizations, linking this with the growing literature on platforms as meta-organizations (Kretschmer et al., 2022). By enabling experimentation, recombination, and trust across heterogeneous actors, PKCs may contribute to broader system-level transitions for system-level problems such as sustainability transition or innovation ecosystems, especially where problems exceed the cognitive and organizational boundaries of individual firms.

6. Conclusions

This study has empirically examined how a Physical Knowledge Contributor (PKC) operates in the context of system-level innovation problems. Through an in-depth case analysis, we have shown how a PKC can function not merely as a knowledge transaction facilitator, but as an orchestrative platform that actively structures multi-actor interactions, enables iterative experimentation, and supports knowledge recombination across organizational boundaries (Trabucchi et al., 2022; Jacobides et al., 2018).

Empirically, the study documents how problem reframing, laboratory-based experimentation, solver coordination, and iterative validation processes unfold across the stages of absorptive capacity (Zahra and George, 2002). The evidence shows that, in the analyzed case, knowledge creation did not occur exclusively within the boundaries of the seeker firm, but was temporarily orchestrated within the platform configuration constituted by the PKC, the seeker, and the solvers.

Theoretically, this study has a threefold contribution.

First, it reframes PKCs as orchestrative platforms rather than purely transactional intermediaries, extending platform research beyond its dominant focus on digital and matchmaking configurations (Täuscher and Laudien, 2018; Parker et al., 2017).

Second, it offers a context-specific extension of absorptive capacity (Zahra and George, 2002) by identifying a boundary condition under which AC unfolds as a cyclical and platform-mediated process, particularly in system-level innovation contexts characterized by high interdependence and uncertainty.

Third, it contributes to the open innovation intermediary literature (Verona et al., 2006; Howells, 2006) by clarifying the distinctive role of physical intermediaries in enabling deep knowledge recombination through experimentation, trust mediation, and orchestration.

Rather than proposing a general reconceptualization of absorptive capacity, our findings suggest that its dynamics may shift when innovation processes are mediated by physical, experimentation-intensive platforms.

Beyond firm-level innovation outcomes, the findings speak to broader societal dynamics. System-level innovation challenges increasingly characterize contemporary socio-technical systems, including sustainability transitions, industrial decarbonization, digital transformation, and the diffusion of emerging technologies such as GenAI. These challenges are marked by interdependence, uncertainty, and the need to coordinate heterogeneous actors with distributed expertise.

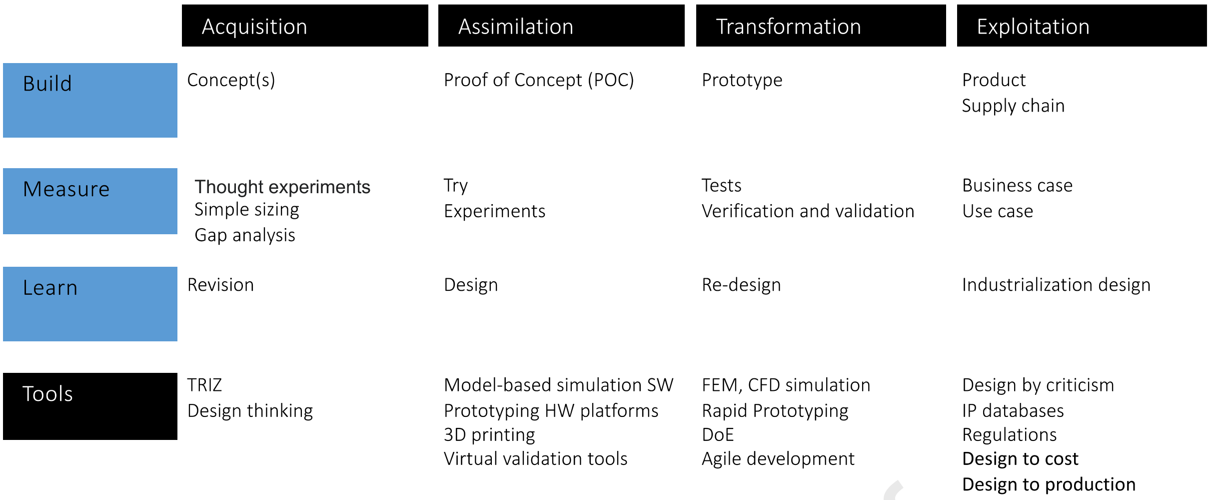
Our analysis suggests that PKCs may operate as meso-level coordination infrastructures within such complex systems. By structuring multi-actor experimentation, mediating trust across organizational boundaries, and enabling iterative knowledge recombination, PKCs contribute to the collective problem-solving capacity of innovation ecosystems. In this sense, they resemble platforms as meta-organizations (Kretschmer et al., 2022), where value emerges from orchestrated interaction rather than bilateral exchange.

Importantly, the tools and mechanisms summarized in Table 8 illustrate how this coordination is operationalized in practice. Analytical reframing, laboratory-based experimentation, agile iteration cycles, and structured engagement mechanisms are not merely firm-level managerial devices; they constitute socio-technical arrangements that enable distributed absorptive capacity across organizations. When system-level problems exceed the cognitive and organizational boundaries of individual firms, such arrangements may become critical for collective learning and coordinated technological change.

While this study does not empirically evaluate societal outcomes, it highlights the organizational architectures that may underpin collaborative responses to complex socio-technological challenges. As an exploratory single-case study (Yin, 2009), this research does not claim statistical generalizability. The mechanisms identified are most likely to apply to project-based, engineering-intensive PKCs characterized by in-house laboratories and multidisciplinary teams. Other configurations of physical intermediaries may exhibit different orchestration dynamics.

Future research could examine whether and how PKCs contribute to sustainability transitions, regional industrial resilience, or the governance of emerging technologies, particularly in contexts where experimentation, coordination, and trust are prerequisites for systemic transformation. Moreover, future research could compare physical and digital intermediaries more systematically, investigate alternative institutional and regional contexts, and explore how PKCs contribute to large-scale socio-technical transitions such as sustainability or digital transformation.

Table 8. The contribution of PKCs to the development of absorptive capacity



	Acquisition	Assimilation	Transformation	Exploitation
Build	Concept(s)	Proof of Concept (POC)	Prototype	Product Supply chain
Measure	Thought experiments Simple sizing Gap analysis	Try Experiments	Tests Verification and validation	Business case Use case
Learn	Revision	Design	Re-design	Industrialization design
Tools	TRIZ Design thinking	Model-based simulation SW Prototyping HW platforms 3D printing Virtual validation tools	FEM, CFD simulation Rapid Prototyping DoE Agile development	Design by criticism IP databases Regulations Design to cost Design to production

References

Afuah, A., Tucci, C.L., 2012. Crowdsourcing as a solution to distant search. *Academy of Management Review*, 37, 355–375.

Agogué, M., Berthet, E., Fredberg, T., Le Masson, P., Segrestin, B., Stoetzel, M., Wiener, M., Yström, A., 2017. Explicating the role of innovation intermediaries in the “unknown”: A contingency approach. *Journal of Strategy and Management*, 10, 19–39.

Ahuja, G., Katila, R., 2004. Where do resources come from? The role of idiosyncratic situations. *Strategic Management Journal*, 25, 887–907.

Al′tshuller, G.S., 1999. *The innovation algorithm: TRIZ, systematic innovation and technical creativity*. Technical Innovation Center, Inc.

Aquilani, B., Abbate, T., Dominici, G., 2016. Choosing open innovation intermediaries through their web-based platforms. *International Journal of Digital Accounting Research*, 16, 35–60.

Arora, A., Athreye, S., Huang, C., 2016. The paradox of openness revisited: Collaborative innovation and patenting by UK innovators. *Research Policy*, 45, 1352–1361.

Bäcklander, G., 2019. Doing complexity leadership theory: How agile coaches at Spotify practise enabling leadership. *Creativity and Innovation Management*, 28, 42–60.

Billington, C., Davidson, R., 2013. Leveraging open innovation using intermediary networks. *Production and Operations Management*, 22, 1464–1477.

Caccamo, M., Pittino, D., Tell, F., 2023. Boundary objects, knowledge integration, and innovation management: A systematic review of the literature. *Technovation*, 122, 102645.

Carnabuci, G., Operti, E., 2013. Where do firms’ recombinant capabilities come from? Intraorganizational networks, knowledge, and firms’ ability to innovate through technological recombination. *Strategic Management Journal*, 34, 1591–1613.

Chesbrough, H., 2003. *Open innovation: The new imperative for creating and profiting from technology*. Harvard Business Press.

Chesbrough, H., Bogers, M., 2014. Explicating open innovation: Clarifying an emerging paradigm for understanding innovation. In H. Chesbrough, W. Vanhaverbeke, J. West (Eds.), *New frontiers in open innovation*. Oxford: Oxford University Press.

Chiaroni, D., Chiesa, V., De Massis, A., Frattini, F., 2008. The knowledge-bridging role of technical and scientific services in knowledge-intensive industries. *International Journal of Technology Management*, 41, 249–272.

Chiaroni, D., Toletti, G., Chiesa, V., 2016. Building absorptive capacity for inbound open innovation: The role of knowledge brokers. *International Journal of Technology Marketing*, 11, 382–398.

Clausena, T., Rasmussenb, E., 2011. Open innovation policy through intermediaries: The industry incubator programme in Norway. *Technology Analysis & Strategic Management*, 23, 75–85.

Coccia, M. (2023). New perspectives in innovation failure analysis: a taxonomy of general errors and strategic management for reducing risks. *Technology in Society*, *75*, 102384.

Cohen, W., Levinthal, D., 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35, 128–152.

Corbin, J., Strauss, A., 2014. *Basics of qualitative research* (4th edition). Sage Publishing.

Crupi, A., Del Sarto, N., Di Minin, A., Phaal, R., Piccaluga, A., 2021. Open innovation environments as knowledge sharing enablers: the case of strategic technology and innovative management consortium. *Journal of Knowledge Management*, 25, 1263-1286.

Danneels, E., Frattini, F., 2018. Finding applications for technologies beyond the core business. *MIT Sloan Management Review*, 59, 73–78.

De Silva, M., Howells, J., Meyer, M., 2018. Innovation intermediaries and collaboration: Knowledge-based practices and internal value creation. *Research Policy*, 47, 70–87.

Dell'Era, C., Magistretti, S., Cautela, C., Verganti, R., Zurlo, F., 2020. Four kinds of design thinking: From ideating to making, engaging, and criticizing. *Creativity and Innovation Management*, 29, 324–344.

Dervojeda, K., Verzijl, D., Nagtegaal, F., Lengton, M., Rouwmaat, E., Monfardini, E., Frideres, L., 2013. Collaborative and open organisational setups and management practices. *EU Business Innovation Observatory*.

Diener, K., Luettgens, D., Piller, F.T., 2020. Intermediation for open innovation: Comparing direct versus delegated search strategies of innovation intermediaries. *International Journal of Innovation Management*, 24, 2050037.

Doloreux, D., & Turkina, E. (2023). Intermediaries in regional innovation systems: an historical event-based analysis applied to AI industry in Montreal. *Technology in Society*, *72*, 102192.

Elmquist, M., Ollila, S., Yström, A., 2016. Beyond intermediation: The open innovation arena as an actor enabling joint knowledge creation. *International Journal of Technology Management*, 72, 273–295.

Enkel, E., Bogers, M., Chesbrough, H., 2020. Exploring open innovation in the digital age: A maturity model and future research directions. *R&D Management*, 50, 161–168.

Ert, E., Fleischer, A., Magen, N., 2016. Trust and reputation in the sharing economy: The role of personal photos in Airbnb. *Tourism Management*, 55, 62–73.

Evans, D.S., 2003. The antitrust economics of multi-sided platform markets. *Yale Journal on Regulation*, 20, 325-381.

Evans, D.S., Schmalensee, R., 2016. *Matchmakers: The new economics of multisided platforms*. Harvard Business Review Press.

Guo, J., Guo, B., 2013. How do innovation intermediaries facilitate knowledge spillovers within industrial clusters? A knowledge-processing perspective. *Asian Journal of Technology Innovation*, 21, 31–49.

Henserson, R., Clark, K., 1990. Architectural innovation: The reconfiguration of existing product technologies and the failureof established firms. *Administrative science quarterly*, 9-30

Howells, J., 2006. Intermediation and the role of intermediaries in innovation. *Research Policy*, 35, 715–728.

Ilevbare, I.M., Probert, D., Phaal, R., 2013. A review of TRIZ, and its benefits and challenges in practice. *Technovation*, 33, 30–37.

Jacobides, M.G., Cennamo, C., Gawer, A., 2018. Towards a theory of ecosystems. *Strategic Management Journal*, 39, 2255–2276.

Jeppesen, L.B., Lakhani, K.R., 2010. Marginality and problem-solving effectiveness in broadcast search. *Organization Science*, 21, 1016–1033.

Katz, M.L., Shapiro, C., 1985. Network externalities, competition, and compatibility. *The American Economic Review*, 75, 424–440.

Klerkx, L., Aarts, N., Leeuwis, C., 2010. Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment. Agricultural *Systems*, 103, 390–400.

Klerkx, L., Leeuwis, C., 2008. Balancing multiple interests: Embedding innovation intermediation in the agricultural knowledge infrastructure. *Technovation*, 28, 364–378.

Klerkx, L., Leeuwis, C., 2009. Establishment and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector. *Technological Forecasting and Social Change*, 76, 849–860.

Kokshagina, O., Le Masson, P., Bories, F., 2017. Fast-connecting search practices: On the role of open innovation intermediary to accelerate the absorptive capacity. *Technological Forecasting and Social Change*, 120, 232–239.

Kretschmer, T., Leiponen, A., Schilling, M., & Vasudeva, G. (2022). Platform ecosystems as meta-organizations: Implications for platform strategies. *Strategic Management Journal*, *43*(3), 405-424.

Lane, P.J., Lubatkin, M., 1998. Relative absorptive capacity and interorganizational learning. *Strategic Management Journal*, 19, 461–477.

Le Masson, P., Weil, B., Hatchuel, A., Cogez, P., 2012. Why are they not locked in waiting games? Unlocking rules and the ecology of concepts in the semiconductor industry. *Technology Analysis & Strategic Management*, 24, 617–630.

Li, X., Gagliardi, D., Miles, I., 2020. Variety in the innovation process of UK research and development service firms. *R&D Management*, 50, 173–187.

Lichtenthaler, U., 2013. The collaboration of innovation intermediaries and manufacturing firms in the markets for technology. *Journal of Product Innovation Management*, 30, 142–158.

Lichtenthaler, U., Ernst, H., 2008. Intermediary services in the markets for technology: Organizational antecedents and performance consequences. *Organization Studies*, 29, 1003–1035.

Lusch, R.F., Nambisan, S., 2015. Service innovation. *MIS Quarterly*, 39, 155–176.

Ma, Y., & Zhu, E. (2025). How network characteristics drive multi-layer innovation networks to achieve boundary-spanning convergence. *Technology in Society*, 103048.

Macchi, M., Rizzo, U., Ramaciotti, L., 2014. From services dealers to innovation brokers: How open innovation paradigm affects incubator activities. Evidence from Italy. *Journal of Intellectual Capital*, 15, 554–575.

Manelli, L., Benedetti, C., Kotlar, J., & Frattini, F. (2025). Bridging moral aspirations and the mundane reality: A grounded study of the process of radical purpose adaptation in a business school. *Journal of Management Studies*.

Miller, D.J., Fern, M.J., Cardinal, L.B., 2007. The use of knowledge for technological innovation within diversified firms. *Academy of Management Journal*, 50, 307–325.

Morisson, A., 2019. Innovation centres as anchor spaces of the 'knowledge city'. *Global Business and Economics Review*, 21, 330–345.

Muzellec, L., Ronteau, S., Lambkin, M., 2015. Two-sided Internet platforms: A business model lifecycle perspective. *Industrial Marketing Management*, 45, 139–150.

Nambisan, S., Bacon, J., Throckmorton, J., 2012. The role of the innovation capitalist in open innovation. *Research Technology Management*, 55, 49–57.

Nambisan, S., Sawhney, M., 2007. A buyer's guide to the innovation bazaar. Harvard Business Review, 85, 109–118.

Natalicchio, A., Petruzzelli, A., Garavelli, A., 2017. Innovation problems and search for solution in crowdsourcing platforms – A simulation approach. *Technovation*, 64, 28-42.

O'Kane, C., 2018. Technology transfer executives' backwards integration: An examination of interactions between university technology transfer executives and principal investigators. *Technovation*, 76, 64–77.

Ollila, S., Elmquist, M., 2011. Managing open innovation: Exploring challenges at the interfaces of an open innovation arena. *Creativity and Innovation Management*, 20, 273–283.

Parker, G., Van Alstyne, M., Jiang, X., 2017. Platform ecosystems: How developers invert the firm. *MIS Quarterly*, 41, 255–266.

Parker, G.G., Van Alstyne, M.W., 2005. Two-sided network effects: A theory of information product design. *Management Science*, 51, 1494–1504.

Patton, M.Q., 2002. Two decades of developments in qualitative inquiry: A personal, experiential perspective. *Qualitative Social Work*, 1, 261–283.

Perez Mengual, M., Danzinger, F., & Roth, A. (2024). Physical interaction platforms: A taxonomy of spaces for interactive value creation. *Creativity and Innovation Management*, *33*(2), 127-138.

Pettigrew, A. M. (1990). Longitudinal field research on change: Theory and practice. *Organization science*, *1*(3), 267-292.

Pham, C.T.A., Magistretti, S., Dell'Era, C., 2023. How do you frame ill-defined problems? A study on creative logics in action. *Creativity and Innovation Management*, 32, 493–516.

Piazza, M., Mazzola, E., Acur, N., Perrone, G., 2019. Governance considerations for seeker-solver relationships: A knowledge-based perspective in crowdsourcing for innovation contests. *British Journal of Management*, 30, 810–828.

Pinarello, G., Trabucchi, D., Frattini, F., Manfredi Latilla, V., 2022. How firms use inbound open innovation practices over time: Evidence from an exploratory multiple case study analysis. *R&D Management*, 52, 548–563.

Ries, E., 2011. *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses.* Crown Currency.

Rippa, P., Quinto, I., Lazzarotti, V., Pellegrini, L., 2016. Role of innovation intermediaries in open innovation practices: Differences between micro-small and medium-large firms. *International Journal of Business Innovation and Research*, 11, 377–396.

Robertson, P.L., Casali, G.L., Jacobson, D., 2012. Managing open incremental process innovation: absorptive capacity and distributed learning. *Research Policy*, 41, 822–832.

Rochet, J.-C., Tirole, J., 2003. Platform competition in two-sided markets. *Journal of the European Economic Association*, 1, 990–1029.

Saldana, J., 2015. *The coding manual for qualitative researchers* (third edition). Sage Publishing.

Savino, T., Messeni Petruzzelli, A., Albino, V., 2017. Search and recombination process to innovate: A review of the empirical evidence and a research agenda. *International Journal of Management Reviews*, 19, 54–75.

Schiuma, G., Santarsiero, F., 2023. Innovation labs as organisational catalysts for innovation capacity development: A systematic literature review. *Technovation*, 123, 102690.

Schneider, S., 2017. What the kaggle acquisition by google means for crowdsourcing. *VentureBeat*. Retrieved from https://venturebeat.com/business/what-the-kaggle-acquisition-by-google-means-for-crowdsourcing/

Sieg, J.H., Wallin, M.W., von Krogh, G., 2010. Managerial challenges in open innovation: A study of innovation intermediation in the chemical industry. *R&D Management*, 40, 281–291.

Siggelkow, N., 2007. Persuasion with case studies. *Academy of Management Journal*, 50, 20–24.

Spithoven, A., Clarysse, B., Knockaert, M., 2011. Building absorptive capacity to organise inbound open innovation in traditional industries. *Technovation*, 31, 10–21.

Spithoven, A., Knockaert, M., Vereertbrugghen, C., 2009. *Collective research centres: A study on R&D and technology transfer involvement*. Belgium Research Series, 11.

Spithoven, A., Vanhaverbeke, W., Roijakkers, N., 2013. Open innovation practices in SMEs and large enterprises. *Small Business Economics*, 41, 537–562.

Täuscher, K., Laudien, S.M., 2018. Understanding platform business models: A mixed methods study of marketplaces. *European Management Journal*, 36, 319–329.

Teece, D.J., 2018. Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world. *Research Policy*, 47, 1367–1387.

Temel, S., Dabić, M., Ar, I. M., Howells, J., Mert, A., & Yesilay, R. B. (2021). Exploring the relationship between university innovation intermediaries and patenting performance. *Technology in Society*, *66*, 101665.

Todorova, G., Durisin, B., 2007. Absorptive capacity: Valuing a reconceptualization. *Academy of Management Review*, 32, 774–786.

Trabucchi, D., Buganza, T., 2022. Landlords with no lands: a systematic literature review on hybrid multi-sided platforms and platform thinking. *European Journal of Innovation Management*, 25, 64–96.

Trabucchi, D., Buganza, T., Verganti, R., 2021. Quantity or quality? Value creation in two-sided platforms. *Technology Analysis & Strategic Management*, 33, 162–175.

Trabucchi, D., Muzellec, L., Ronteau, S., Buganza, T., 2022. The platforms' DNA: Drivers of value creation in digital two-sided platforms. *Technology Analysis & Strategic Management*, 34, 891–904.

Van Rijnsoever, F.J., 2020. Meeting, mating, and intermediating: How incubators can overcome weak network problems in entrepreneurial ecosystems. *Research Policy*, 49, 103884.

Vanhaverbeke, W., Chesbrough, H.W., West, J., 2019. *Open innovation: Researching a new paradigm*. Gildan Media.

Vanhaverbeke, W., Van de Vrande, V., Chesbrough, H., 2008. Understanding the advantages of open innovation practices in corporate venturing in terms of real options. *Creativity and Innovation Management*, 17, 251–258.

Verganti, R., 2016. The innovative power of criticism. *Harvard Business Review*, 94, 88–95.

Verona, G., Prandelli, E., Sawhney, M., 2006. Innovation and virtual environments: Towards virtual knowledge brokers. *Organization Studies*, 27, 765–788.

Von Nell, P.S., Lichtenthaler, U., 2011. The role of innovation intermediaries in the markets for technology. *International Journal of Technology Intelligence and Planning*, 7, 128–139.

West, J., Bogers, M., 2014. Leveraging external sources of innovation: A review of research on open innovation. *Journal of Product Innovation Management*, 31, 814–831.

West, J., Bogers, M., 2017. Open innovation: Current status and research opportunities. *Innovation*, 19, 43–50.

Yin, H. T., Wen, J., & Chang, C. P. (2022). Science-technology intermediary and innovation in China: Evidence from State Administration for Market Regulation, 2000–2019. *Technology in Society*, *68*, 101864.

Yin, R.K., 2009. Case study research: *Design and methods*. Sage Publications.

Zahra, S., George, G., 2002. Absorptive capacity: A review, reconceptualization, and extension. *The Academy of Management Review*, 27, 185–203.

Interviewee ID	Type	Company	Role	Experience	Background	Education	Country
BT0	OII	BlueThink	Director	12	Mechanical engineering	MSC	UK
BT1	OII	BlueThink	Project Manager	10	Biomedical engineering	PhD	IT
BT2	OII	BlueThink	Project Manager	6	Electronic engineering	MSC	IT
BT3	OII	BlueThink	Business Development	> 20	Economics	MSC	IT
BT4	OII	BlueThink	Operations	3	Materials engineering	MSC	IT
BT5	OII	BlueThink	Project Manager	4	Mechanical engineering	MSC	IT
BT6	OII	BlueThink	Operations	2	Biomedical engineering	MSC	IT
BT7	OII	BlueThink	Project Manager	12	Materials engineering	PhD	IT
BT8	OII	BlueThink	Project Manager	6	Mechanical engineering	MSC	IT
BT9	OII	BlueThink	Operations	4	Computer Science engineering	MSC	UK
BT10	OII	BlueThink	Operations	4	Automation engineering	PhD	IT
BT11	OII	BlueThink	Chief Operating Officer	15	Materials engineering	PhD	IT
Sk1	Seeker	RWH	Project Manager	10	Mechatronics engineering	MSC	IT
Sk3	Seeker	OGI	Innovation manager	> 20	Mechanical engineering	MBA	IT
Sk4	Seeker	OGI	R&D Project Manager	15	Materials engineering	MSC	IT
Sl1	Solver	LaserTech	Director	> 20	Phisics	MSC	IT
Sl2	Solver	LaserTech	Technical Manager	10	Mechanical Engineering	MSC	IT
Sl3	Solver	OptoTech	Optical Designer	15	Optics	PhD	IT

Acquisition

	Specific objective	Tools and Practices	Players	Evidences from Case RWH	Evidences from Case OGI
Build	Devise a set of concepts that meet the Seeker's need, identify the technologies to be acquired that will enable it to be realised.	• Brainstorming • Creative prob Solving (Design Thinking) • Creative prob Solving (TRIZ)	PKC Seeker	RobotWareHouse , a specialist in robotics for automated warehouses, asks BlueThink (BT) to address the problem of protecting pick-up robots' batteries from cold conditions found in refrigerated warehouses. (Learn) BT conduces a brainstorming, involving RWH experts and BT engineers with multidisciplinary skills and experience in different industries, with two distinct aims: understanding how to reframe the problem and identifying industrial fields that faced the same problem. (Measure) In parallel, BT experts deconstruct the robot into subsystems using creative problem-solving methodologies and map all subsystems' interactions involving the battery pack. (Learn) The problem is reframed from “protecting pick-up robots' batteries from cold” to “finding solution to lower the cost of ownership of pick-up robots related to batteries”. (Build) Many different strategies to reach a so formulated goal are listed and discussed with the seeker. A scouting activity was conducted to identify multiple enabling technologies for each solution strategy. Concepts of solution are generated. (Measure) The most promising concept have a first validation by simple dimensioning and gap analysis with respect the original field of application of enabling technologies. (Learnd) A concept based on Supercapacitors – a power storage technology used in light rails – emerged as promising.	The Seeker wishes to develop a short-range, wireless system enabling at building the digital tween of a subsea structure. The Seeker has no definite idea of which technology to use. (Learn) An analysis of technical, scientific and patent literature is conducted to identify possible solutions originated in sectors far from the oil & gas. For example, technologies born in the telecommunications sector are considered. (Measure) In parallel, the problem is analysed to understand implementation constraints, expected system performance, ... (Build) Concepts based on different technologies are generated in collaboration with the Seeker, and specific Solvers are identified. (Measure) The most promising concepts are analysed by identifying specific subsystems, their interactions and carrying out simple dimensioning. For example, communication performance in water, energy consumption, etc. (Build) This analysis and the interaction with specific solvers allow the refinement of the concept considered promising: an optical communication technology based on laser emitters. (Learn) From an initial check on IP, it appears that there are no impediments to "freedom to operate”. (Measure) The analysis of the chosen concept presents three main bottlenecks which will need to be examined in depth: energy consumption, robustness to vibrations, and emitters and receiver performance in water. Energy consumption is verified by simple calculations, based on the declared consumption of emitters and assumptions on the data transmission system consumption. The influence of vibrations and strategies to mitigate them can be addressed at this stage just by analogy with other applications. Finally, different types of emitters and receivers are identified, many of which have never been tested for performance in water (Learn need)
Measure	Deconstruct, analyse to understand the limits and potential of a concept and the technologies identified to realise it.	• Multiscale Analysis (TRIZ) • Cause/Effect Analysis (TRIZ) • Thought experiments (Design Thinking) • Simple Dimensioning • Gap Analysis	PKC		
Learn	Analysing the problem, understanding the state of the art of technology and the constraints imposed by IP, to guide the search for solutions.	• Scientific/Technical Literature • IP databases	PKC Solvers		

Assimilation

	Specific objective	Tools and Practices	Players	Evidences from Case RWH	Evidences from Case OGI
Build	Appropriating the identified technologies through the realisation of Proof of Concept.	• 3D Printing • Breadboard Hw Prototyping • Hw Prototyping Platforms • Model Based Simulation SW	PKC Seeker Solvers	At this stage a conceptual solution based on supercapacitors technology has been identified. To understand the feasibility of bringing the technology into the pick-up robots, RWH initially proposes to develop a battery pack and directly integrate it into a robot. BT proposes to leverage its lab facilities to build a simplified setup for severe testing of critical aspects: performance at low temperature and the adequacy to cope with a regime of acceleration/deceleration and changes of direction. (Build) a PoC in which the robot's traction subsystem and a smaller battery pack (1/4 the size) are placed in a horizontal refrigerator is realized. (Measure) The implemented setup allow to test the innovative battery pack with with many more degrees of freedom than the field test, eg: (i) controlling temperature in a wither range; (ii) performing the charge and discharge cycle of the battery pack in 1/4 the time. (Learn) The PoC allows BT and the Seeker to explore the technology's limitations in functionality, performance, and integrability, which are crucial for aligning the stakeholder vision in the transition from this initial experiment to the subsequent solution design phase.	At this stage a conceptual solution has been identified and the enabling technologies to develop it have been identified. The need to understand the feasibility of bringing the technology into the new application context emerges for the Seeker and BT. (Build) A number of laser emitters and optical receivers are purchased, and a test setup is built consisting of a narrow tank several metres long that will be filled with water to test the performance of the devices in water. The realised setup is very simple and took a few weeks to set up. (Learn) A study is conducted to understand what the typical operating conditions of an underwater context are (temperature, salinity, turbidity, vegetation conditions of the algae, disturbance factors) and how they can be reproduced in the laboratory. For example, it turns out that a drug normally used to treat stomach-ache is used in many scientific researches to reproduce turbidity under controlled conditions. (Measure) The simple set-up created allows the testing of transmission performance in water at different temperatures, salinity levels and water turbidity. The setup also makes it possible to acquire information on energy consumption in relation to different operating conditions. (Learn) The concept is refined based on the information gained from the experimentation. Energy consumption and battery pack sizing calculations are updated. The information gained on signal-to-noise ratio, signal attenuation, and the number of lost data packages provides an initial level of confidence in the feasibility of the concept.
Measure	The acquired technologies are tested to verify the implementation in the new concept.	• Data Acquisition Tools • Easily reconfigurable spaces for experimentation	PKC		
Learn	Frame the technology in the Seeker's implementation. Refine and/or modify the product concept, exploiting the features discovered by experimenting with a new technology.	• Data analysis Tools • Scientific literature comparison • Information from Solvers	PKC Seeker		

Transformation

	Specific objective	Tools and Practices	Players	Evidences from Case RWH	Evidences from Case OGI
Build	Creating prototypes to first validate the most critical aspects, and then their integration into the final product.	• HW, SW, FW design tools • 3D Printing • HW Prototyping platforms (Arduino, Rapsberry, ..)	PKC Seeker Solvers	After the first validation of the supercapacitors-based concept, an intensive and recursive activity of co-design in carried out involving the seeker and selected solvers. (Build) the first prototyping run focussed on building some minor improvements to the previous PoC and on realizing a power management algorithm. (Measure) This improvements allowed the tests to be automated and thus intensified. (Learn) The collected data enables the accurate design of a new prototype. DoE is used to plan an extensive test campaign. (Build) A new prototype with dedicated PCB electronics is realized. (Measure) The test results puts on the light a severe limitation of the supercapacitors-based concept. (Learn) The idea of a hybrid battery pack made by supercaps and lithium batteries emerge as a possible solution. (Build) The prototype of a hybrid power pack is realized, and a new experimental campaign is planned by DoE. (Measure) Tests give confidence on the hybrid system and provide information essential to design an optimized system. (Learn) The IP situation of this solution is verified.A final prototype is designed, built (Build) and tested (Measure).	To develop and verify critical subsystems and every aspect of integration, prototyping and testing cycles are performed. (Build) The first prototype focuses on optical communication and neglects all other implementation aspects, utilizing general-purpose and bread-board electronics. (Measure) Communication system performance is evaluated based on various factors: focus angle, optical system characteristics, and data packages length and frequency. (Learn) The idea of using multiple emitters in conjunction with an intelligent control that selects the emitter with optimal power consumption and signal-to-noise ratio, has emerged. (Build) A second prototype integrating multiple emitters is built, breadboard subsystems are replaced by a custom-designed PCB electronics realized by an external laboratory. The battery pack is designed with the support of a solver. (Measure) A new measurement campaign is carried out. In parallel, a finite-element simulation is conducted to estimate vibrations to which the device will be subjected in the field. (Learn) Tests permit to gain confidence in the multi-emitter concept. The IP situation of this solution is verified. (Build) A dedicated PCB device, is built, with no effort to miniaturize the device at this stage. This third prototype is tested (Measure) to create an optimised design (Learn). (Build) The fourth prototype, which features optical windows and sealed connectors to work at depths of up to 4,000 meters, is co-designed with a Solver experienced in creating bathyscaphe and hyperbaric chambers. All the HW and FW electronics is designed in-house by BT. Different solvers' subsystems converge in BT's laboratories, where they are assembled and tested (Measure) A new measurement campaign is carried out to focus (Learn) some 'minor' improvements . A final prototype is built (Build) and tested (Measure).
Measure	Recursive test runs to validate first, limits and criticalities of the implemented technologies and then, reliability and performance of the integrated solution.	• Finite Elements Modeling (FEM) • FMEA, FMECA • Flexible Lab Structure • General pourpose acquisition systems	PKC Seeker Solvers		
Learn	Each prototyping and testing cycle leads to validating certain solutions and/or modifying them in the subsequent re-design. Some solutions are abandoned and replaced by alternative technologies.	• Agile Development • Design of Experiments (DoE)	PKC Seeker Solvers		

Exploitation

	Specific objective	Tools and Practices	Players	Evidences from Case RWH	Evidences from Case OGI
Build	Industrialise the product with features that make it usable, manufacturable, maintainable, and reliable. Building the supply chain.	• User Interaction • Design to cost • Design to manufacturing • Design to maintenance	PKC Seeker	(Learn) Integrability assessments involving the Seeker allow BT's experts to refine the design of the device to be integrated. (Build) These activities were followed by design-to-cost and design-to-manufacturing tasks to ensure the transition to an industrial product. (Measure) Use Cases and focus groups allows the evaluation of capex and opex costs. (Learn) This information allows to estimate the reduction in the cost of ownership granted by the solution. Detailed verifications are carried out to assess the Intellectual Property landscape to protect the concept.	(Learn) A set of information about the installation context of the device is acquired, (Build) based on this information, a connection node to the ship, the anchorages for the device, and the SW for pre-processing and transferring data to and from the ship are designed. (Build) Ten devices are constructed for the field test and the test is planned. Small changes are made to the design to allow easier connection of sensors and instruments to the device. Small design changes are made to allow high-volume production, which for this type of device means 500-1000 pieces per year. The supply chain for the first deliveries is defined. (Learn) the rules, practices and regulations of field operations are studied and consequently (Measure) the installation procedure is tested. (Build) a field test is planned, and the equipment required to conduct it is built - partly by BT, partly by the Seeker and its supply chain. The support needed to conduct the field test is provided.
Measure	Making certain product characteristics, related to quality and use, objective. Refine the business model.	• Focus group, workshops • Use Cases • Business Cases	PKC Seeker		
Learn	Assess perceptions and feedback from clients and/or users. Verify compliance with regulations. Verify the possibility of protecting IP.	• Statistical analysis about perceived quality evidencies • IP Databases • Regulations	PKC Seeker		

	Acquisition	Assimilation	Transformation	Exploitation
Multidisciplinarity, in-house expertise, teams of specialists	Problem deconstruction Problem reframing	Cognitive alignment Knowledge mobility	Systemic solution ideation Knowledge recombination	Market and cost analysis, Regulatory & IP framework
Physical Assets, experimenting, prototyping, testing		Hands-on assimilation Tacit to explicit knowledge	Agile prototyping Concepts validation	UX & functional evaluation Industrialization support
Solvers Network, small, well mapped trusted relationships	Direct searches, Creative problem solving	Trust mediation	Co-creation	

Discussion – PkC's supporting Seeker's Absorptive Capacity

	Acquisition	Assimilation	Transformation	Exploitation
Build	Concept(s)	Proof of Concept (PoC)	Prototype	Product Supply Chain
Measure	Thought experiments Simple Dimensioning Gap Analysis	Try Experiments	Tests Verifivation and Validation	Business Case Use Case
Learn	Revision	Design	Re-design	Industrialization Design
Tools	TRIZ Design Thinking	Model based Simulation Sw Prototyping Hw Platforms 3D Printing Virtual Validation Tools	FEM, CFD simulation Rapid Prototyping DoE Agile Development	Design by Criticism IP Databases Regulations **Design to cost** **Design to production**

From Brokerage to Orchestration: Physical Open Innovation Intermediaries as Platforms for System-Level Knowledge Creation

Highlights

- System-level innovation requires platform-orchestrated knowledge creation rather than simple knowledge brokerage
- Physical open innovation intermediaries operate as two-sided platforms that actively orchestrate absorptive capacity
- Absorptive capacity unfolds as a cyclical, interorganizational process rather than a firm-bounded linear sequence
- Physical laboratories enable learning-by-doing assimilation and deep knowledge recombination across distant domains
- Well-mapped solver networks favor radical recombination over scalable but shallow crowdsourcing models

Daniel Trabucchi and Federico Frattini have nothing to declare.
Giordano Pinarello is the founder of the company object of the study, as coherent with the participatory nature of the study presented in the methodology section.

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GenAI, in aprticular ChatGPT, has been used for proof reading the paper and grammar check.