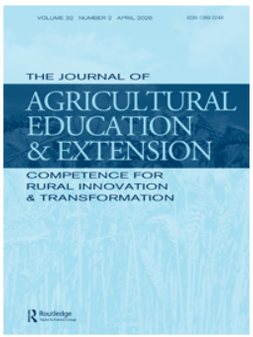

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Learning to innovate. Innovation brokers and co-creation in EIP-Agri operational groups in Rhineland-Palatinate

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ABSTRACT

Purpose: This paper examines knowledge integration within EIP-AGRI Operational Groups (OGs) in Rhineland-Palatinate, Germany, focusing on innovation brokers' roles in facilitating co-creation between farmers, researchers and advisors.

Methodology/Approach: We studied four OGs through expert interviews and document analysis. Using communities of practice theory, we analysed broker practices, knowledge integration mechanisms and enabling conditions for co-creation.

Findings: Innovation brokers function as knowledge orchestrators facilitating integration through adaptive facilitation, multi-modal translation and network cultivation. Successful OGs demonstrate characteristics of communities of practice (CoP) including mutual engagement, joint enterprise and shared repertoire. Key enabling conditions include trust-building, process transparency and field-based co-learning, while challenges include administrative delays, institutional silos and rigid regulations.

Practical implications: Programs should support partnerships based on existing relationships, provide resources for brokerage activities and develop flexible funding mechanisms. Institutional frameworks should support rather than constrain CoP.

Value: This study advances understanding of transdisciplinary approaches in Agricultural knowledge and innovation systems (AKIS) by investigating how institutionalized networks facilitate learning through CoP, offering insights into tacit knowledge brokerage within innovation frameworks.

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1. Introduction

Agricultural systems face unprecedented challenges from climate change, biodiversity loss and resource depletion. Rhineland-Palatinate, a federal state in the southwest of Germany with an agricultural size and structures similar to those of Belgium or Slovenia represents a region with diverse agricultural landscapes of livestock, crop and viticultural production (European Commission 2020; Ministry of Agriculture, Forestry and Food of

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the Republic of Slovenia 2023; StatBel 2024). Effects of environmental crises manifest here like in many European contexts in increasing water scarcity, pests, extreme weather events and soil degradation (e.g. Cleeves 2023; Odersky and Löffler 2024). Traditional agricultural production, practices and knowledge systems are increasingly reaching their limits in addressing the complex challenges in agricultural production systems while the livelihoods of agricultural practitioners are threatened.

Agricultural knowledge and innovation systems (AKIS) are thus indispensable to foster innovations for adapting to climate change and addressing the era of multiple crises within agriculture. The main challenge of AKIS is to integrate diverse knowledge forms across its functional domains. The European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) institutionalized an interactive innovation approach through Operational Groups (OGs), creating conditions for knowledge exchange between farmers, researchers, advisors and other stakeholders 'to foster competitive and sustainable farming and forestry that "achieves more and better from less"' (EIP-AGRI 2023).

This article reads OGs through the lens of Communities of Practice (CoP) in order to better understand processes of knowledge integration, co-creation and learning. Particularly, we investigate the specific strategies and practices innovation brokers employ to facilitate knowledge integration and co-creation across different domains of expertise.

So far, several Horizon Europe projects topically related to this research area and have contributed to developing innovation support practices. Projects such as AgriSpin (2015-2017) compiled innovation support methods through cross-visits and peer learning among advisory services across Europe, while the i2connect project (2019-2024) exemplarily focused on strengthening advisors' capacities in innovation support. These projects generated valuable practical knowledge about innovation management methods in collaboration with advisory services, yet there remains limited scientific reflection on how these methods effectively integrate different knowledge types and facilitate social learning in innovation partnerships.

Recent research has examined knowledge integration practices in agricultural innovation partnerships, revealing important insights and gaps relevant to the study of OGs. Fieldsend et al. (2021) review of 200 agricultural innovation projects demonstrates that successful knowledge integration in this context depends heavily on the involved intermediaries' ability to balance formal project requirements with informal learning processes. Their follow-up study (2022) particularly highlights how innovation brokers' activities shape knowledge exchange patterns – a finding directly relevant to understanding OGs dynamics, though the specific practices enabling this remain underexplored.

Šūmane et al. (2018) establish the importance of integrating farmers' experiential knowledge with scientific expertise, however their work leaves questions of how this integration practically occurs within structured innovation partnerships like apparent in OGs. This gap is particularly relevant as Gardeazabal et al. (2021) identify persistent challenges in managing power dynamics and trust-building between scientific and practical knowledge holders in agricultural innovation processes.

Addressing this, Ingram et al. (2018) concept of 'co-translation' offers a promising framework for understanding knowledge integration in OGs, emphasizing the need for active intermediation between different knowledge systems. However, their work,

like Klerkx and Leeuwis's (2008) foundational study on innovation intermediaries, focuses primarily on structural conditions rather than specific practices of knowledge integration. This leaves a critical gap in understanding how innovation brokers actually facilitate knowledge integration processes within the context of OGs.

These findings in recent scientific literature point to a clear research need:

> Examining the specific practices and conditions through which innovation brokers enable knowledge integration in OGs, particularly how they balance formal project requirements with the informal learning processes essential for combining scientific and practical knowledge.

Given this research background, this study employs an explorative approach and examines knowledge integration practices within EIP-AGRI OGs in Rhineland-Palatinate. In order to do so, we address three research questions:

(1) How do established practices and interactions within OGs reflect key characteristics of CoP, particularly regarding knowledge integration?
(2) How do innovation brokers facilitate knowledge integration, co-creation and learning processes in OGs?
(3) Which conditions enable or hinder successful knowledge integration in OGs and how do brokers adapt their practices accordingly?

Following this, we proceed by employing a theoretical framework based on CoP, innovation brokerage and transformation in AKIS (Section 2), followed by methodology (Section 3), empirical findings on broker practices and knowledge integration processes (Section 4), discussion of theoretical and practical implications (Section 5) and conclusions with recommendations for strengthening knowledge brokerage for innovations in agriculture (Section 6).

2. Theoretical framework

2.1. Communities of practice in agriculture

CoP represent informal networks of practitioners who share a common domain of interest, engage in collective learning and develop shared practices through regular interaction (Lave and Wenger 1991). In agricultural innovation contexts, these communities take shape within structured frameworks like EIP-AGRI OGs while maintaining their essential characteristics of mutual learning and knowledge exchange.

Agricultural CoP operate through three key dimensions (Wenger 1999; see also Mills 2011) that are particularly relevant for understanding knowledge integration in innovation partnerships:

(1) Mutual engagement in agricultural innovation practices: Farmers, researchers and advisors actively participate in joint problem-solving and knowledge creation, moving beyond traditional roles of knowledge providers and recipients.
(2) Joint enterprise in developing sustainable farming solutions: Members collectively define goals and approaches, combining scientific expertise with practical farming experience to address complex challenges.

(3) Shared repertoire of tools and methods: The community develops common languages, practices and understanding that bridge different knowledge systems and enable effective collaboration.

Central to these dimensions is Wenger's concept of reification – the process of giving form to understanding by producing objects that congeal experience and tacit knowledge into thingness (Binder 1996; Wenger 1999, 58f). In agricultural innovation contexts, such reification manifests through the creation of standardized protocols, shared technical vocabulary or documented best practices. These objects serve to coordinate activities across knowledge domains while remaining open to reinterpretation through practice. Successful knowledge integration in OGs thus partly depends on their ability to develop such concrete forms that can bridge different domains of expertise while maintaining their meaning-making potential.

This framework is particularly valuable for agricultural innovation as it acknowledges both the potential and limitations of collective learning processes. While CoP can accelerate innovation through rapid knowledge exchange and validation of new practices, their informal and established nature can also reinforce existing practices that may resist necessary changes (Darr, Hoffmann, and Helmle 2014). In the context of sustainability transitions, this presents a key challenge: how to leverage CoP learning capacity while overcoming potential resistance to transformative change.

The strength of CoP in agricultural innovation lies in their ability to facilitate multidirectional learning, where farmers' experiential knowledge engages in genuine dialogue with technical and scientific expertise (Kline and Rosenberg 1986). Within EIP-AGRI OGs, this manifests as topically focused, structured yet informal exchanges enabling knowledge integration across different domains of expertise. However, realizing this potential requires careful facilitation to balance formal project requirements with the informal learning processes essential for innovation.

Still, the potential of CoP to enable agricultural transformation depends on certain conditions. Key among these are opportunities for regular interaction, mutual trust among members and openness to different forms of knowledge (see e.g. Vermeulen et al. 2018). The literature further identifies additional conditions for successful knowledge integration in innovation processes. Studies also emphasize the importance of establishing trust between actors through regular face-to-face interactions and transparent communication about goals and expectations (Ingram et al. 2018). Linked to this, authors also highlight the necessity of iterative reflection processes that allow for continuous adaptation and deepening of mutual learning (Klerkx 2020).

In the context of EIP-AGRI OGs, this is especially relevant where diverse actor groups need to develop shared understandings and practices on the basis of different disciplinary backgrounds. The success of knowledge integration thus depends not only on the formal project structure but significantly on the OG member's ability to act under conditions of mutual learning and co-creation.

Building on these foundational conditions, CoP offer potential for agricultural innovation and adaptation by:

- Creating safe spaces for experimentation with new practices.
- Bridging different knowledge systems to generate novel solutions.

- Enabling rapid diffusion of successful innovations through trusted networks.
- Facilitating social learning about climate impacts and potential responses.
- Building collective and adaptive capacity through shared learning.

To realize this potential, agricultural development initiatives increasingly recognize the need to work with and through existing CoP rather than bypassing them with formal structures (Dolinska and d'Aquino 2016). This shift from more formal transfer approaches toward supporting social learning processes enables farmer-led innovation and adaptation while building on the conditions and methods that facilitate successful knowledge integration.

2.2. Innovation brokers as intermediaries

Innovation brokers serve as critical intermediaries in supporting and strengthening CoP within AKIS. Building on the social learning perspective established in CoP theory, brokers facilitate knowledge integration, co-creation and learning processes (Klerkx 2020; Müller, Sutter, and Wohlgemuth 2020).

Following the theoretical framework developed so far, we identify three essential functions that innovation brokers perform in relation to CoP:

- Knowledge articulation: Making tacit knowledge explicit by helping practitioners verbalize their experiential understanding and translate between different forms of knowledge.
- Process facilitation: Creating conditions for social learning to emerge by structuring interactions, managing group dynamics and supporting collective knowledge creation.
- Network formation: Creating and maintaining connections between diverse actors, identifying potential community members and fostering relationships that enable knowledge exchange.

The EIP-AGRI program institutionalizes this brokerage role through agricultural advisory organizations, creating formal spaces for informal knowledge exchange. Within this framework, OGs represent structured attempts to foster CoP while maintaining their essential characteristics of mutual engagement and shared learning. Research shows that successful brokers balance formal support functions (e.g. funding acquisition, proposal development) with informal facilitation that enables CoP to share knowledge practices. Recipients particularly value brokers' abilities to identify compatible partners and create spaces for mutual engagement – key conditions for CoP to emerge (Parzonko, Wawrzyniak, and Krzyżanowska 2022).

However, brokering between different knowledge systems presents distinct challenges. Brokers must not only navigate between and bridge different domains of expertise and types of knowledge, additionally they translate between knowledge practices in a dialogic and collaborative manner, creating a *middle ground* where shared understandings emerge. This requires not only a specific mindset, but specific knowledge and a high degree of social competence (Ingram et al. 2018). This translation work requires bridging different epistemologies, timeframes and communication styles (Klerkx and Leeuwis 2008).

To address these challenges, brokers must develop what Wenger terms 'knowledgeability' (Omidvar and Kislov 2014, 270) – a complex capability encompassing three key dimensions:

(1) Boundary competence: The ability to move transversally between different knowledge domains and communities while creating meaningful connections between diverse knowledge practices.
(2) Practical connectivity: Skills to make knowledge 'work' by ensuring its applicability across different contexts and its translation into actionable practices.
(3) Translation capacity: The ability to mediate between different epistemic communities, enabling mutual understanding and knowledge exchange across conceptual and practical boundaries.

The effectiveness of innovation brokerage in fostering CoP thus depends on brokers' ability to:

- Facilitate legitimate peripheral participation of new members.
- Support mutual engagement through both formal and informal interactions.
- Enable joint enterprise through shared goals and activities.
- Help develop shared repertoires of tools and practices.
- Maintain connections across community boundaries.

This theoretical framework helps understand how OGs can function as institutionalized CoP, with brokers playing crucial roles in facilitating knowledge integration while maintaining the emergent, practice-based character essential for collective learning and innovation.

3. Methodology

3.1. Research design

This study employed a qualitative case study approach examining EIP-AGRI OGs in Rhineland-Palatinate, Germany. The region's established AKIS and active participation in EIP-AGRI made it suitable for exploring innovation brokerage within CoP.

The case study design allowed for an in-depth examination of how innovation brokers facilitate knowledge integration and co-creation processes in multi-stakeholder environments. By focusing on a small number of cases, we could explore the complexity of social interactions, knowledge exchange processes and the specific practices employed by brokers in real-world contexts. This approach aligns with our research questions that seek to understand how OGs function as CoP, how brokers facilitate knowledge integration and what conditions enable or hinder successful knowledge co-creation.

3.2. Data collection and analysis

Primary data collection involved 4 semi-structured expert interviews with innovation brokers and Operational Group members, conducted in early 2025. These innovation

Table 1. Overview over interview partners.

Interview partner	Operational Group	Interview Duration
Mittermeier (M)	DaLeA	91 min
Wagener (W)	MUNTER	86 min
Steinfort (S)	Nachhaltigere Milch	107 min
Hübener (H)	KI Rebschnitt	72 min

brokers were selected based on their direct involvement in facilitating OG activities, with each representing a different OG in Rhineland-Palatinate. Interview requests were sent to several OGs in the region and the final selection of participants was based on their willingness to participate and their diverse backgrounds, with some having explicit practitioner experience in farming, consulting or research alongside their brokerage role.

The selection of the four OGs (DaLeA, MUNTER, Nachhaltigere Milch and KI Rebschnitt) aimed to capture diversity in innovation types (technical, social and organizational), agricultural focus areas (soil management, efficiency, viticulture and water management) and sustainability challenges addressed. This diversity provided a robust empirical foundation to explore our theoretical framework across different contexts while remaining manageable for in-depth qualitative analysis.

Interviews lasted between 72 and 107 min (see Table 1) and followed a semi-structured protocol focusing on three main areas: (1) the formation and evolution of the OG as a community of practice, (2) specific brokerage practices employed to facilitate knowledge integration and (3) enabling conditions and challenges encountered throughout the innovation process. All interviews were audio-recorded with permission and subsequently transcribed verbatim for analysis. Interview and document data was complemented by the analysis of Operational Group proposals, meeting minutes and progress reports. These documents provided valuable contextual information about the formal structure, objectives and evolution of each OG, allowing for triangulation with interview data. The subsequent analysis followed an iterative coding approach using MAXQDA, focusing on identifying patterns in knowledge integration and brokerage activities. The coding process followed a framework-guided approach, with initial codes derived from close reading of the transcripts and informed by our theoretical framework of communities of practice and innovation brokerage, followed by categorization into broader themes related to our research questions. The analysis was conducted through constant exchange between the authors, with codes and interpretations regularly discussed and refined. To enhance validity, preliminary findings were shared with interviewees, giving them opportunity to provide feedback on our interpretations. The exploratory nature of this research, while not claiming statistical representativeness, offers valuable insights into how theoretical concepts of innovation brokerage manifest in practice. Findings contribute to understanding broker-facilitated knowledge integration in AKIS.

Table 2 below provides an overview of the four OGs examined in this study. The DaLeA group, established in 2021, focuses on developing living mulch systems for soil conservation while maintaining agricultural productivity. NIKIZ, completed in 2020, worked on sustainable input application methods with a particular focus on pest management. KI-Rebschnitt, a newer initiative started in 2022, applies artificial intelligence to

Table 2. An overview over the researched OGs characteristics and functions.

Group Name	Innovation	Broker Background	Network Composition	Sustainability Challenge	Agricultural Area/ Topic
DaLeA	Technical, Social, Organizational	Private Sector (Agricultural Advisory Service)	Farmers, Researchers, Advisors	Maximizing soil protection while maintaining agricultural productivity	Soil Management & Conservation Agriculture
NIKIZ	Technical, Social	Research Institution & Advisory Services –	Farmers, Researchers, Agricultural Consultants	Enhancing on-farm efficiency while reducing environmental impact	Input Efficiency – Testing of more sustainable input application methods.
KI-Rebschnitt	Technical, Organizational	Research Institution	Farmers, Researchers, Industry Partners	Balancing farm profitability with ecological goals	Biomass & Renewable Agriculture
Munter	Technical, Social, Organizational	Private Sector & Research Institutions	Farmers, Researchers, Policymakers, Advisors	Preventing erosion and managing extreme weather impacts	Water Management & Erosion Control

viticulture pruning practices to balance productivity with ecological goals. Munter, the longest-running group (since 2019), has developed innovative approaches to water management and erosion control and is now in a scaling phase to broaden implementation of their findings.

4. Empirical findings

The table provides an overview of the four OGs examined in this study, highlighting their innovation types, broker backgrounds, network compositions and the sustainability challenges they address, serving as a reference for the detailed findings presented in the following sections.

4.1. EIP-AGRI operational groups as communities of practice

The interviews provide in-depth insights about how the OGs developed organically from existing relationships and shared interests. The formation of CoP played a central role in the interviews, as the interviewees used the description of how their OGs formed to both exemplify their distinct approach to their topic and how they interacted over time. The organic formation of OGs as CoP was particularly evident in the DaLeA project, where the innovation broker (M) described a bottom-up approach that contrasted with formal partnership structures:

> For us, the path to project application wasn't 'I have a lead partner and I'm looking for OG partners' […] rather for us it was exactly the opposite. We had the OG and the topic first – M.

This quote is exemplifying a bottom-up organisational pattern that was found frequently across the interviews and documented in final reports and further materials. The CoP can thus be framed as organically emerging social entities, meaning that especially knowledge integration and co-creation within the OGs was supported by a shared, non-hierarchical and topic bound group context. Linking to our theoretical framework, these groups demonstrated the core dimensions of CoP through varying approaches to mutual engagement, joint enterprise efforts and shared repertoire development. However, throughout the process of establishing cooperation, several hurdles could be identified investigating the cooperation within the OGs. The NIKIZ innovation broker (S) highlighted the challenges of developing shared repertoire – a key dimension of CoP according to Wenger (1999) – particularly around terminology:

> We actually had the problem that, in the beginning, we couldn't agree on many terms. Each partner somehow had a different term from their everyday field for the same thing. It took us some time until we developed a common nomenclature – S.

In solving communicative dissonances and finding common ground, this specific OG eventually decided to stick to the methods and tools of carbon accounting that were already established in practice to some degree, but less sophisticated from a scientific angle. Transferring knowledge from existing sources into applied contexts, the KI-Rebschnitt project illustrated this in an intensive collaboration between technology experts, agricultural advisors and winegrowers evolving into a functioning community

of practice. Through regular digital meetings occurring multiple times per month, continuous knowledge-sharing workshops and collaborative field evaluations, the group created conditions for mutual learning and knowledge co-creation. The community developed shared practices particularly around data collection and annotation, with up to ten members collaborating on training data preparation in the field for an AI system used to automatize plant recognition. This process required developing common understanding bridging both technical requirements and agricultural expertise.

Similarly, the NIKIZ project demonstrated how a community of practice can evolve to address emerging agricultural challenges. Through weekly virtual meetings between active members across institutions and direct field-level communication between researchers and farmers, NIKIZ established robust patterns of mutual engagement. The group developed shared practices around pest monitoring protocols and variety testing procedures, while showing remarkable adaptability when a leafhopper (*Pentastiridius leporinus*) emerged as a critical threat to their operations (see also Therhaag et al. 2024). The CoP's approaches showed an overall great mitigation potential through thorough knowledge integration and combined systematic field trials with regular stakeholder dialogues, both digitally and face-to-face. The MUNTER project demonstrated this too on how CoP emerge around complex sustainability challenges in agriculture, negotiating management systems for energy plant cultivation.

Beyond seeking to innovate agricultural production patterns through community action, taking into account the economic viability linked to many of the innovations subject to EIP-AGRI, MUNTER, as several other OGs, showed a consensus to not seek to negatively impact the productive margins of agriculture while adding to societal benefit through innovation:

> The innovation was about whether, for example, erosion protection or also flood protection or water storage could be integrated into agricultural production in such a way that it simultaneously doesn't reduce the benefits for agriculture while also creating high benefits for society – W.

Thus, the group developed shared understandings and practices for integrating energy crop cultivation with environmental protection. Their approach to knowledge integration was also characterized by systematic field trials combined with regular stakeholder dialogues, both digitally and face to face, leading to practical solutions that balanced economic viability with ecological requirements.

In the DaLeA project, the community of practice formed around developing and testing 'living mulch' systems. The group established shared experimental protocols and evaluation methods, combining scientific rigor with practical farming knowledge. Their practice evolution was particularly evident in the adaptation of cultivation techniques based on collective learning from field trials:

> In our OG, we were an extremely practice-oriented project and we developed our shared practices directly in the field, because it was the only possibility with our machinery. I wouldn't say we had strict routines, since everyone worked differently, but we developed shared terms and ideas. I can't even count how many times we discussed the term 'permanent living mulch,' and at some point – interestingly, this also spread beyond our group – everyone automatically associated 'living mulch' with clover, because that's what we used – M.

This quote demonstrates that a term 'living mulch', not yet widely established in practice and which is used to refer to various nurse crops, was eventually eponymous with clover, because this term was widely used in practice. It underlines, that knowledge integration also requires the flexibility to adapt more abstract concepts such as 'living mulch' to practical understandings.

4.2. The role of innovation brokers

Underlined by the project layouts in the final reports and project documents, interviewees provided insight into the processes and skills involved in innovation brokerage. Innovation brokers played distinct yet complementary roles across all projects, adapting their approaches to specific contexts while maintaining core brokerage functions. One especially pertinent metaphor emerged from an interviewee who described their role as a 'human border collie ' – M, highlighting their function in herding and bringing people together. This requires a delicate balance: '[…] walking a tightrope between boss and buddy ' – M.

A common motive, which emerged from the interviews was the role of translator between researchers and farmers. Translation work encompassed understanding both perspectives, establishing a common understanding of the practical challenges, identifying knowledge gaps, structuring existing knowledge and making knowledge 'work' in practice. An innovation broker from DaLeA (M) exemplified the ability to move between different knowledge domains:

> I am a farmer with a scientific background and interest and that's exactly what it is and then I can … Well, I'm really a practicing farmer, so I can understand the practitioners – M.

This dual identity enabled effective translation between scientific and practical knowledge systems.

In the KI-Rebschnitt project, the project coordinator in his role as innovation broker facilitated translation between AI researchers and vineyard practitioners, helping establish common technical vocabulary and shared understanding of pruning requirements.

To ensure effective knowledge exchange, brokers continuously adapted the collaboration format:

> At first, we had two meetings a week, but that wasn't really useful. Now we do structured discussions once a week and allow smaller groups to work independently in between. This way, we don't waste time, but we still make sure knowledge flows – H.

This demonstrates the broker's ability to adapt working structures and routines to the needs of stakeholders.

In the NIKIZ project, translation work was central to ensuring farmers could engage meaningfully with research findings. One broker emphasized the importance of explaining scientific terminology to practitioners:

> I knew when the student said, 'We only have this standard deviation,' […] I knew what they meant and I could explain to the farmer what standard deviation is – M.

This illustrates how brokers act as bridges between different knowledge systems, ensuring that complex academic insights are communicated in ways that are relevant and actionable for practitioners.

Within MUNTER, brokers helped articulate complex interactions between energy crop production and environmental protection measures. Several conditions were identified as favouring successful knowledge brokerage, with trust building emerging as particularly crucial. As the MUNTER broker (W) emphasized:

> Effective co-creation only happens when there is mutual respect. It doesn't work if academics, farmers and policymakers see each other as separate groups. Trust comes first – only then can real knowledge exchange happen – W.

Brokers in the DaLeA project supported the codification of farmer experiences with living mulch systems, making widespread experiential knowledge accessible in a structured way. As one interviewee described:

> We took what was coming from practice, where someone would say, 'We need more knowledge on this,' and turned it into something systematic. We are not fundamental researchers, but we focus on applied science that helps bridge the gap – W.

This highlights the broker's role in transforming informal, practice-driven insights into codified structures and systems (texts, agreements) that could then be negotiated across various formats across various formats, including discussions on sustainable agriculture. Process facilitation emerged as another crucial function, with brokers maintaining regular structured interactions across all projects. They adapted meeting formats between digital and in-person gatherings based on project needs, organized field-based co-learning events and developed frameworks for evaluation of prototypes by practitioners. Their network formation activities focused on identifying and connecting complementary expertise across institutional boundaries while maintaining engagement of diverse stakeholders throughout project lifecycles.

Regarding network building, the interviews revealed that:

> The best network is the practitioners on the ground … because they exchange among themselves more through direct channels than any administrative networks or scientific networks – M.

However, the challenge remained that knowledge exchanged at the 'ground-level' needed to be mediated and integrated throughout the larger circles within the OGs. Brokers in projects like NIKIZ addressed this by coordinating activities across multiple research institutions while managing multi-channel communication between stakeholders.

4.3. Knowledge integration and co-creation processes

Linked to this, the analysis revealed several knowledge integration practices that were adapted to specific project contexts aimed at mediating different knowledge forms. Structured interaction formats proved fundamental, with projects like KI-Rebschnitt implementing regular digital meetings up to multiple times per week. These were complemented by field-based workshops and demonstrations alongside formal evaluation sessions that combined practitioner and researcher perspectives.

The NIKIZ project expanded on these approaches through multiple channels of knowledge integration. The project implemented regular operational group meetings combining virtual and in-person formats, winter assemblies for comprehensive knowledge sharing and field days integrating practical demonstrations with scientific

discussion. They developed standardized monitoring protocols and evaluation frameworks, particularly for pest management and variety testing. Digital tools, including an online pest calendar and prediction models, facilitated continuous knowledge exchange between stakeholders.

Field-based co-learning emerged as a particularly effective approach across all projects. DaLeA conducted on-farm trials with systematic data collection. KI-Rebschnitt did this too, combined with testing prototypes under real vineyard conditions. In addition to structured trials, the projects actively adapted their methods based on field observations and farmer feedback. The Nachhaltigere Milch innovation broker (S) articulated the critical importance of this collaborative approach:

> For us, it was crucial that the researchers weren't just working on their own. We needed joint testing in the fields, not just data collection in isolated research settings – S.

The MUNTER project employed co-learning by establishing demonstration plots for energy crop cultivation. In NIKIZ, collaborative monitoring activities linked research and practice through joint variety trials involving farmers, researchers and industry partners. These practical activities were supported by iterative development cycles, where regular feedback loops between research and practice enabled progressive refinement of methods and approaches. Documentation played a crucial role in knowledge integration throughout the projects, with groups developing standardized evaluation frameworks and technical guidelines. This systematic approach aimed at capturing and sharing knowledge supported both immediate project needs and longer-term knowledge transfer.

4.4. Enabling conditions and challenges encountered

Several key conditions emerged as important for knowledge integration and co-creation processes, while persistent challenges were also identified.

Essential enabling conditions included robust technological infrastructure and tools supporting regular communication and exchange. All innovation brokers interviewed detailed that the use of ICT, ranging from groupware to messenger groups, formed integral part of the working routines. Digital tools for exchange of information were essential to generate dynamic and self-propelling workflows between partners without necessitating direct interaction of the innovation brokers as coordinator. Concomitantly, as detailed above, hands-on practical evaluation of solutions developed was equally crucial to fuel co-creation. Recurrent feedback loops with varying stakeholders, at times extending beyond the core innovation partnership to the wider network, were crucial to stimulate reflection, broaden acceptance for the co-creation process and adjust the solutions developed to stakeholder needs.

Process transparency, especially regarding financial project implementation proved to be an enabling factor for creating trust among project partners as was detailed by one innovation broker:

> Especially when it comes to finances, maximum transparency is crucial. Because as soon as money is involved, there's a fight. And at these OG meetings, after the welcome, the very first point was always finances, along with the controlling process that I would set up – showing bank statements, showing the disbursement requests – so that everyone always knew who was getting how much money – M.

Accordingly, management skills and process knowledge were considered as essential aspects of innovation brokerage. As was detailed by another innovation broker, taking on the role of advocate of primary producers involved in the partnership vis-à-vis grant authorities and paying agencies proved enormously helpful for co-creation and keep practitioners motivated. These involved practices of caretaking, when needs of practitioners regarding the administrative project implementation were prioritised:

> And so we said, 'They always have to come first; they have to be doing well, they must be well provided for' – S.

Another crucial enabling condition for trustful co-creation stressed by brokers – less surprisingly – related to the human factor of mutual respect and personal relationships, which enabled project partners to bridge socio-economic hierarchies and roles: 'There is no co-creation if there isn't already a willingness to engage with the other, to enter another level or another world and to value it ' – M. While some innovation brokers considered commonalities and social proximity such as 'personal fit' and a 'common base' of partners, also regarding engagement in leisure activities and uniting experiences (such as a trip to Eurotier fair for an award) as a prerequisite, others considered mutual respect originating from recognition of difference and diverse forms of knowledge and practical expertise:

> Communication at eye level is primarily due to there being great respect among everyone and that this is not, shall we say, perceived differently just because one person is an academic, another is a craftsman and yet another, say, someone from an administration or elsewhere – W.

Regardless of the 'origin' of mutual respect, it was stressed as a main condition for co-creation as an open and trustful form of partnership working to emerge. This involved highly developed interpersonal and social skills on behalf of innovation brokers, involving great sensitivity for individual wellbeing and group dynamics.

Eventually, time was considered one of the most pertinent enabling condition as well as constraint for co-creation to emerge. This involved taking time to get to know each other and building social relationships as well as time for administrative tasks.

At the same time, innovation brokers encountered several challenges that impeded effective co-creation among stakeholders. One of the most pressing issues was the significant delay in payments, which created a considerable financial strain on farms and diminished their motivation. As one interviewee recounted:

> Yes, it took a very long time before any money actually arrived, which became a financial burden for the farms and significantly affected their motivation … if there's no progress or improvement, we might just withdraw – S.

A second challenge arose from sector-specific silos within public administration. Authorities in water management, as detailed by an innovation broker, typically address farmers only in terms of regulations, rather than pursuing proactive and integrative discussions.

'In practice, the water management sector only talks with agriculture about the relevant regulations ' – W.

This narrow focus on complying with regulations hindered broader, forward-looking collaboration in the development of land-use systems. Another related obstacle lies in the defence of disciplinary boundaries, which generates resistance among stakeholders unrelated to the project's main objectives but rooted in the need to safeguard one's own position and competences:

> We kept running into difficulties and resistance that usually had nothing to do with our core objectives but were rooted in more fundamental assessments by nature conservation on endemic species – W.

Compounding this issue is the lack of urgency within governmental bodies, whose less immediate 'pain points' delay the regulatory adjustments essential for co-creation:

> This sense of urgency … the state government often doesn't have that … – W.

Moreover, slow law-making processes delay the transfer and application of innovative solutions. As one innovation broker noted:

> We started incorporating agroforestry systems into the relevant regulations in 2018 … hopefully in the first quarter of 2025 it will finally be legally integrated … we've spent a full seven years on this. That's just far too long – W.

Related to this is the high degree of regulation in Germany, which renders modifications of established rules exceedingly challenging:

> The density of regulations here … the deeper we codify something, the more difficult it becomes to change it again … – W.

Finally, despite valuable insights and workable solutions co-created by various stakeholder groups, these efforts often fail to translate into policy change. The tenor within the interviews revealed that without timely institutional support and a clear route to alter regulations, the widespread uptake of successful co-creative outcomes is discouraged.

Taken together, these constraints – ranging from delayed funding and institutional silos to the rigidity of regulations – underscore the need for more agile, transparent and responsive administrative structures, especially in the policy domain of innovation funding.

5. Discussion

5.1. Theoretical implications

Our findings substantially advance the understanding of how CoP theory applied to the researched innovation partnerships. The empirical evidence from Rhineland-Palatinate's OGs revealed how institutionalized innovation frameworks can successfully foster authentic CoP while maintaining their essential characteristics of mutual engagement, joint enterprise and shared repertoire (Wenger 1999).

The observed bottom-up formation pattern of OGs, e.g. exemplified in the above quote '[…] we had the OG and the topic first […]' – M, demonstrates how formal innovation structures can emerge from and reinforce existing informal learning networks. This formation pattern aligns with Wenger's (1999) emphasis on mutual engagement

as a foundational element of CoP, where relationships and shared interests precede formal structures. Our findings suggest that organically emerging groups demonstrate greater potential for knowledge co-creation as members already share baseline understanding and trust, extending Dolinska and d'Aquino's (2016) work by showing how institutional frameworks like EIP-AGRI can successfully build upon rather than bypass existing CoP. This finding extends Dolinska and d'Aquino's (2016) work on farmer-led innovation by showing how institutional frameworks like EIP-AGRI can successfully build upon rather than bypass existing CoP.

The development of shared terminology and practices across the OGs, particularly evident in the DaLeA project's evolution of 'living mulch' understanding, demonstrates Wenger's concept of reification – the process by which communities give form to their experience by producing objects (like documents, terms, tools) that congeal this experience into thingness. This reification was visible in how abstract concepts were transformed into tangible protocols, standardized evaluation frameworks and shared technical vocabulary. This process was notably bidirectional, with technical terms being both simplified for practical application and enriched through practitioner experience, also supporting Ingram et al. (2018) concept of co-translation in agricultural innovation.

5.2. Innovation brokers as facilitators of knowledge integration

Our analysis reveals innovation brokers operating with what Omidvar and Kislov (2014) term 'boundary competence' – the ability to move between different knowledge domains while creating meaningful connections. The dual identity of brokers, exemplified by the DaLeA coordinator who combined farming experience with scientific background, enabled effective translation between knowledge systems, directly addressing the challenge identified by Šūmane et al. (2018) regarding the integration of farmers' experiential knowledge with scientific expertise.

The analysis further reveals innovation brokers operating as what could be termed knowledge orchestrators – moving beyond simple intermediation to actively shape conditions for knowledge integration. The metaphor of the 'human border collie' emerged from our data as a powerful illustration of how brokers navigate multiple boundaries while maintaining group cohesion, extending Klerkx and Leeuwis's (2008) conceptualization of innovation intermediaries.

The brokers' ability to facilitate knowledge integration while maintaining authentic CoP adds empirical weight to Šūmane et al. (2018) theoretical framework for integrating formal and informal agriculture related knowledge. Our findings suggest that successful brokers achieve this through three interrelated practices:

(1) Adaptive facilitation: Adjusting intervention levels based on group dynamics and project phase.
(2) Multi-modal translation: Moving between scientific, technical and practical knowledge domains.
(3) Network cultivation: Maintaining both formal and informal connections between stakeholders.

These practices extend beyond Klerkx's (2020) identified broker functions, suggesting a more nuanced understanding of how brokers operate within institutionalized innovation frameworks. The critical role of trust-building in broker effectiveness aligns with Vermeulen et al. (2018) findings on the importance of trust in facilitating transformative adaptation in agriculture. Our research extends Klerkx and Leeuwis's (2008) work on innovation intermediaries by highlighting the affective and relational dimensions of brokerage that enable effective knowledge integration across institutional boundaries. Brokers' social role in bridging divides between different professional cultures ensures that collaboration is based on mutual understanding rather than hierarchical knowledge flows.

5.3. Conditions for successful knowledge integration

Our research identifies several critical conditions for successful knowledge integration that both support and challenge existing theoretical frameworks. The importance of technological infrastructure alongside face-to-face interaction suggests a more complex relationship between formal and informal knowledge exchange than previously recognized in the literature. The experience of the NIKIZ project particularly highlights how resource constraints and emerging challenges can impact knowledge integration processes. This finding extends Fieldsend et al. (2021) work by demonstrating how successful knowledge integration depends not only on broker capabilities but also on institutional support structures and resource availability.

The findings suggest that theoretical models of AKIS could seek to better account for the dynamic interplay between formal and informal knowledge networks. Also, the role of material and institutional constraints in shaping knowledge integration could be taken into account more closely while underlining the importance of flexibility in broker practices and institutional frameworks.

While our theoretical framework of CoP and innovation brokerage proved valuable for understanding OG dynamics, several findings emerged that extended or challenged our initial expectations. Particularly the varying importance of digital communication tools across different OGs were surprising. While our framework emphasized face-to-face interaction as central to CoP formation, the KI-Rebschnitt group demonstrated that intensive digital collaboration could effectively support community development when complemented by strategic in-person field activities. This suggests a more complex relationship between virtual and physical engagement than previously theorized. We also observed significant differences in how brokers navigated institutional constraints, with MUNTER developing sophisticated strategies for cross-sectoral engagement not predicted by theory. Similarly, the DaLeA experience revealed unexpected tensions between scientific and practical nomenclature, where the group ultimately prioritized practice-based terminology (adopting 'living mulch' specifically for clover) over scientific language, questioning assumptions about knowledge hierarchies in innovation processes. These surprises highlight the need for theoretical frameworks that better account for the contextual adaptability of both CoP and brokerage functions, particularly regarding digital/physical interaction patterns and navigating institutional complexities.

Additionally, the field-based co-learning approach observed across the cases exemplifies what Dolinska and d'Aquino (2016) describe as empowering farmers for innovation

through CoP, where knowledge is co-created rather than transferred. This emphasis on situated learning in authentic contexts directly reflects Lave and Wenger's (1991) foundational concept that learning occurs through participation in shared practices. Our findings also address Gardeazabal et al. (2021) identified challenge of managing power dynamics between scientific and practical knowledge holders by demonstrating how shared physical spaces enable different forms of expertise to be equally valued.

5.4. Limitations and future research directions

While our study offers valuable insights into knowledge integration practices within AKIS, several limitations should be acknowledged. The focus on Rhineland-Palatinate, while allowing for detailed analysis, limits generalizability to other contexts. Additionally, the relatively small sample size of four OGs, though providing explorative and rich qualitative data, enhanced by additional document analyses, may not capture the full range of broker practices and knowledge integration strategies.

Future research could usefully explore comparative analyses across different regional contexts within and across innovation programs. Further investigation of the topic employing quantitative and qualitative tools, especially with regard to digital means of innovation could be useful to enrich the scientific discourse.

5.5. Practical implications for AKIS development

Our findings have implications for the design and implementation of AKIS. The success of brokers in facilitating knowledge integration while maintaining authentic CoP suggests that AKIS frameworks should:

(1) Provide flexible support structures that can adapt to emerging challenges.
(2) Recognize and support both formal and informal knowledge networks.
(3) Invest in broker training that emphasizes adaptive facilitation skills.
(4) Create institutional frameworks that support long-term community building.

These recommendations extend beyond current AKIS design principles, emphasizing the need for institutional frameworks that support rather than constrain the organic development of CoP.

5.6. Policy implications

Our findings on innovation brokerage in OGs have important implications for agricultural innovation policies and institutional frameworks. The challenges identified by innovation brokers – particularly regarding administrative delays, institutional silos and regulatory rigidity – point to specific areas where policy interventions could enhance the effectiveness of knowledge co-creation in AKIS.

5.6.1. Funding mechanisms and administrative processes

A critical issue identified across all studied OGs was the significant delay in payments, creating financial strain particularly for farm partners. As one broker noted, 'it took a

very long time before any money actually arrived, which became a financial burden for the farms and significantly affected their motivation' (S). This finding aligns with Fieldsend et al. (2021) observation that administrative barriers can significantly impede the effectiveness of multi-actor partnerships in agriculture. To address this, policy frameworks could: – Implement more streamlined payment processes with shorter approval cycles – Provide advance funding options for farm partners with limited financial reserves – Reduce administrative burdens through simplified reporting requirements – Create dedicated support functions to assist practitioners with administrative tasks.

5.6.2. Cross-Sectoral integration

Our research revealed that sector-specific silos within public administration pose significant barriers to innovation. The MUNTER broker highlighted how water management authorities typically interact with agricultural stakeholders only through regulatory frameworks rather than collaborative innovation approaches. This sectoral fragmentation limits the potential for integrated solutions to complex agricultural sustainability challenges. Policy approaches to overcome these silos could include: – Establishing cross-departmental innovation units with representatives from different sectors – Creating joint funding initiatives that require collaboration across water management, agriculture and conservation departments – Developing coordination mechanisms to align policies across sectors affecting agricultural innovation – Incentivizing collaborative approaches that address multiple policy objectives simultaneously.

5.6.3. Regulatory flexibility for innovation

The lengthy processes for regulatory adjustment emerged as a significant constraint on innovation implementation. As illustrated by one broker's experience with agroforestry systems, 'We started incorporating agroforestry systems into the relevant regulations in 2018 … hopefully in the first quarter of 2025 it will finally be legally integrated … we've spent a full seven years on this' (W). This timeframe is incompatible with the urgency of agricultural adaptation to sustainability challenges. Policy mechanisms to enhance regulatory responsiveness could include: – Creating regulatory sandboxes or innovation zones where new approaches can be tested under modified regulatory frameworks – Developing fast-track processes for regulatory assessment of promising innovations – Establishing adaptive management frameworks that allow for iterative policy refinement based on innovation outcomes – Incorporating feedback mechanisms from innovation practitioners into regulatory development processes These policy implications extend beyond the EIP-AGRI program itself to the broader institutional ecosystem within which agricultural innovation occurs. As emphasized by Klerkx (2020), advisory services and innovation brokers can only fulfill their transformative potential when supported by enabling institutional frameworks. Our findings suggest that while innovation brokers can effectively facilitate knowledge integration at the project level, realizing the full potential of co-created innovations requires complementary policy innovations that enhance institutional responsiveness and cross-sectoral collaboration.

6. Conclusions and outlook

This study has examined knowledge integration practices within EIP-AGRI OGs in Rhineland-Palatinate, focusing on the role of innovation brokers in facilitating co-creation and learning processes. Through our analysis of OGs and their work throughout the project we have identified key mechanisms through which innovation brokers enable effective knowledge exchange between diverse agricultural stakeholders.

Our research reveals that OGs can successfully function as institutionalized CoP, maintaining essential characteristics of mutual engagement, joint enterprise and shared repertoire while operating within formal innovation frameworks. This success depends significantly on the innovation brokers' ability to navigate multiple boundaries and facilitate knowledge integration through adaptive facilitation, multi-modal translation and network cultivation.

The study identified several critical findings that advance our understanding of agricultural innovation processes:

(1) **The potential of organic formation**: Successful OGs evolved best departing from pre-existing relationships and shared interests rather than being artificially constructed, highlighting the importance of building on established trust and communication channels.
(2) **Brokers as knowledge orchestrators**: Innovation brokers are actively shaping conditions for knowledge integration by bringing diverse stakeholders toward common goals while allowing sufficient autonomy for genuine co-creation.
(3) **Adaptive facilitation as key broker skill**: Successful brokers continuously adjust their intervention levels and communication strategies based on group dynamics, project phases and emerging challenges.
(4) **Field-based co-learning as essential practice**: Knowledge integration is most effective when anchored in concrete, shared field experiences that bridge theoretical and practical understanding.
(5) **Importance of institutional support**: While broker skills are critical, their effectiveness depends heavily on flexible institutional frameworks and adequate resources that can adapt to emerging innovation needs.

These findings demonstrate how OGs can serve as effective platforms for addressing complex agricultural sustainability challenges when supported by skilled innovation brokers and appropriate institutional structures.

Based on our findings, we offer several recommendations for strengthening knowledge brokerage for agricultural innovation. Innovation brokers should cultivate 'boundary competence' by developing familiarity with multiple knowledge domains while maintaining the ability to translate between them. They need to prioritize trust-building through regular, structured interactions that recognize the value of all knowledge forms and balance formal project requirements with space for informal knowledge exchange and emergent learning. Developing adaptive facilitation skills that can respond to changing group dynamics and project needs is essential, as is establishing multiple channels for knowledge exchange that combine digital and face-to-face formats.

For those designing innovation programs, our research suggests recognizing and supporting the formation of innovation partnerships based on existing relationships and shared interests, while providing dedicated resources for brokerage activities throughout the innovation process. Evaluation frameworks that value both tangible outputs and the development of CoP are needed, alongside support structures for innovation brokers, including training, peer exchange and institutional backing.

While our study offers valuable insights into knowledge integration practices within AKIS, we acknowledge several limitations. The focus on Rhineland-Palatinate, while allowing for detailed analysis, limits generalizability to other contexts. Additionally, the sample size of four OGs, though providing rich qualitative data, may not capture the full range of broker practices and knowledge integration strategies.

Future research could usefully explore comparative analyses across different regional and national contexts within the EIP-AGRI framework, longitudinal studies of broker impacts on agricultural practice change and network development and approaches to digital brokerage in agricultural innovation. Developing metrics and evaluation frameworks that can capture the multifaceted contributions of innovation brokers would be valuable, as would examining how insights from local innovation processes can be effectively scaled to influence broader agricultural systems.

The findings underscore that agricultural innovation requires more than technical solutions – it demands careful attention to the social processes through which knowledge is integrated, shared and transformed. As agricultural systems face increasingly complex sustainability challenges, the role of innovation brokers as facilitators of these social processes becomes ever more vital. The CoP that emerged within the studied OGs represent promising models for how institutionalized innovation frameworks can support informal learning processes and knowledge co-creation. By continuing to refine these approaches, AKIS can enhance their capacity to generate the sustainable solutions needed for a future in which agriculture achieves more and better from less.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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