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Developing innovation capabilities through Programme Communities of Practice: Evidence from Wales

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ABSTRACT

This paper presents empirical evidence on how publicly funded programme communities of practice (CoPs) enhance learning and innovation activities at the organisational and inter-organisational level, which in turn develop organisation's innovation capabilities. It draws upon studies on two programme CoPs in Wales and presents eight case studies. Findings reveal, firstly, that CoP can promote the learning of new tools, knowledge, and technologies to encourage product and service innovation. Secondly, CoPs can promote innovative solutions to common challenges, such as implementing circular economy principles. Thirdly, CoP can facilitate collaborative inter-organisation innovation. Our paper answers the recent call for empirical research on the role of publicly funded collaborative projects that support business to innovate. It also expands the understanding of adopting CoP for management education. Practically the framework we developed can guide policy makers and practitioners on how universities can share risk, knowledge, and support organisations to develop their innovation capabilities and achieve sustainable development.

1. Introduction

Management education has long been linked to knowledge creation and sharing, through which business can learn new knowledge, tools and techniques to innovate (Jun and Kim, 2022; Loebbecke et al., 2016). Moreover, management education can support businesses to enhance their understanding of grand challenges (e.g. sustainability) and in response, they can develop and implement solutions to help address these challenges (Van Rijnsoever et al., 2023; Moratis & Melissen, 2022). Studies have shown that management education plays an essential role in solving 'wicked' problems and this requires sustainability-focused educational experiences (Van Rijnsoever et al., 2023; Moratis & Melissen, 2022; Earle & Leyva-de la Hiz, 2021). For instance, university programmes can help business to improve their daily operations through the implementation of circular economy (CE) principles (Clifton et al., 2024; Clifton & Walpole, 2023; Liu et al., 2023). The CE is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible (European Parliament, 2023). Management education can enable organisations to engage with contemporary societal challenges (Elkjaer, 2022).

Communities of Practice (CoP) provide a novel approach to effectively mobilise change within an organisation (Clifton, Kyaw, et al., 2024; Smith et al., 2019), facilitating interaction among stakeholders (Liu et al., 2023; Walpole et al., 2022), and promoting sustainability agendas (Borges et al., 2017). In fact, CoP often enable informal relations among participants with the specific purpose of

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learning, creating and sharing knowledge (Wenger et al., 2002). As a situated practice, it provides an important source of knowledge formation (Müller & Ibert, 2015; Wenger, 1998) and enable solutions development in CE transformation (Liu et al., 2023; Walpole et al., 2022). The formation of a cohort of learners into a CoP provides a new dimension for management education, a CoP can be integrated into education programmes, serving as a pedagogical device for developing managers capabilities, which can be described as a Programme Community of Practice (PCoP) (Smith et al., 2019) if theoretical content is introduced to the cohort.

There is a paucity of literature that explores PCoP as mechanisms to develop the innovation capability of practitioners to support the implementation of CE principles. Studies of CoP, within management education, have largely focused on their use within leadership development and sharing of existing knowledge (Walpole et al., 2022). Wenger's (1998) conceptual framework defines a CoP as having three core elements; a domain of interest (a specific common interest and shared purpose), a community (relationships between participants that form them into a community), and practices (processes and rituals that are shared by the community participants), and yet there is a paucity of empirical studies that explore how a CoP or PCoP can support organisational innovation and publicly funded collaborative projects (De Laurentis et al., 2024; Franzò et al., 2023).

Therefore, exploring the role of CoP/PCoP in business innovation and supporting sustainable development is of real value. Firstly, to tackle climate change antecedents and other grand challenges, coproduction of solutions is needed through collective learning, and CoP can serve this purpose. Secondly, many organisations suffer from low levels of innovation and thus new pedagogical methods are required to address this issue. A recent UK Government report indicated the development of organisational innovation capabilities is problematic and to help address this market failure the Industrial Strategy set a target of raising public and private sector investment in Research and Development (R&D) from 1.7 % to 2.4 % by 2027 (UK Government, 2021). In Wales, the setting of this study, output per hour worked was 15.9 % below the UK average in 2021 (Office for National Statistics, 2021), suggesting the urgency of innovation capability development. Moreover, innovation activities through engagement with external innovation actors, known as open innovation, is widely seen as a mechanism to enhance business innovation (Chesbrough, 2003; Chesbrough & Brunswicker, 2014). Open innovation can potentially support organisations to collaboratively develop innovation projects and new solutions to solve emerging problems. Potentially, PCoP can help facilitate collaborative learning, best practice sharing, and co-creation of new solutions, which can be implemented in businesses. This includes publicly funded PCoP, which link government, universities and industry on a regional level to enhance innovation activity and capabilities (Liu et al., 2023).

Based on the highlighted research, there is value in exploring the impact of PCoP on developing innovation capabilities and supporting sustainable development. Therefore, this study poses the following question, "How can publicly funded Programme Communities of Practice enhance organisations' innovation capabilities to achieve sustainable development goals?" The paper draws upon studies on two programme PCoP in Wales and presents eight case studies. It aims to address the empirical research gap on the role that PCoP can play in enhancing innovation capabilities and how they might facilitate co-creation of solutions to emerging challenges. In fact, the challenge practitioners face in applying innovation theory to practice has long been articulated as the '*Knowing Doing Gap*' (Pfeffer & Sutton, 1999) which is seldom bridged by traditional educational approaches (Walpole et al., 2022; Wenger-Trayner & Wenger-Trayner, 2020).

This study contributes to the nascent literature that suggests contemporary management education should evolve to include peer to peer interaction, systems perspectives, reflective and critical thinking to bridge this gap (Bugallo-Rodríguez & Vega-Marcote, 2020; De Laurentis et al., 2024; Walpole et al., 2022). Here the study aims to offer a framework that can guide policy makers and practitioners on how universities can share risk and knowledge, and support organisations to develop their innovation capabilities to achieve sustainable development goals.

The remainer of the paper is structured as follows. Section 2 reviews literature on developing innovation capabilities and CoP. Section 3 details the research method. In Section 4, we present findings from the eight case studies. This is followed by Section 5, the development of propositions and the generation of a framework. Further discussion and concluding remarks are made in Section 6.

2. Literature review

2.1. Innovation capabilities

Innovation capabilities within firms refers to their ability to effectively generate, develop, and implement innovative ideas and solutions (Aas & Breunig, 2017; Janssen & Castaldi, 2018). Key aspects to enhance innovation capabilities include a creative culture (Lounsbury et al., 2018), R&D activities alongside new product development (NPD) and new service solutions (NSS) (Steinmo et al., 2022), cross functional collaboration (Moaniba et al., 2018), flexible and responsive process (Urbinati et al., 2022), market knowledge (Aas & Breunig, 2017), open innovation (Chesbrough, 2003), and leadership development and learning (Smith et al., 2019). Open innovation is crucial as firms may source external knowledge to addresses an innovation issue, potentially doing so more quickly and at lower cost than solving the issue inhouse (Chesbrough, 2003; Tapscott & Williams, 2010). Specifically, there are inbound (Chesbrough, 2003; Dodgson et al., 2006; Laursen & Salter, 2004), outbound (Chesbrough, 2003; Danneels & Frattini, 2018; Piller & Walcher, 2006) and coupled open innovation activities (Chesbrough & Brunswicker, 2014) jointly absorbing new knowledge and developing new paths to market with new technologies in the form of joint venture, alliance and consortium (Chesbrough & Brunswicker, 2014).

At an inter-organisational level, knowledge and policy support infrastructure may stimulate collective learning, continuous innovation and entrepreneurial activity (Chen et al., 2013; Granados & Pareja-Eastaway, 2019; Tödtling & Trippl, 2005). Franzò et al. (2023) demonstrated that publicly funded collaborative projects can support businesses to develop new products and services. The alignment and interaction of innovation among industry, universities, and government, known as the Triple Helix, can support innovation and thereby generate greater economic and societal benefits (Etzkowitz, 2008; James et al., 2022) through facilitating the

implementation of innovation policy (Chen et al., 2013). Recent research suggests innovation policy is evolving towards transformative innovation policy (Clifton, Kyaw, et al., 2024; Haddad et al., 2022), addressing sustainability issues (Foxon & Pearson, 2008; Schot & Steinmueller, 2018) and grand challenges (Raven & Walrave, 2020).

It is noted that innovation capabilities rely increasingly on internal and external collaboration, managing risks, enhancing organisational learning, and developing an open innovation strategy (Angelshaug et al., 2023). The transition towards a sharing economy has dispersed knowledge and advances in information and communication technologies have led to increased interconnectivity between individuals and organisations (Loebbecke et al., 2016). Accordingly, more research is needed to explore the role that different forms of external collaboration such as networks, consortia, communities and platforms play in enhancing innovation capability (Knoch, 2022; West & Bogers, 2017). This paper answers a recent call for empirical research on the role of publicly funded collaborative projects that support businesses to innovate (Franzò et al., 2023) and contributes to the innovation capability development literature, referenced above. Using the case of Wales (UK), a region with poor innovation levels and productivity challenges relative to the UK average (Office for National Statistics, 2021), this paper provides insights for practitioners and policymakers who face the challenge of enhancing innovation and productivity through policy interventions.

2.2. Communities of practice (CoP)

2.2.1. Concepts of CoP and PCoP

Knowledge in specific fields can be shared within and between individuals and organisations through CoPs, the concept was originally conceived to explain practitioner learning (Brown & Duguid, 1991), and more recently innovation across organisational and spatial settings (Amin & Roberts, 2008; Müller & Ibert, 2015). A working definition of a CoP can be posited as '*groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis'* (Wenger et al., 2002, p. 4). From this, a CoP is conceptualised as a set of informal relations and understandings that develop in mutual engagement on an appropriate joint enterprise, as well as groups with the specific purpose of learning, creating and sharing knowledge (Wenger et al., 2002). Such situated practice is thus a source of knowledge formation (Müller & Ibert, 2015; Wenger, 1998) promoting organisational learning and thus advancing organisational innovation (Swan et al., 2002). Based on this link between situated practice and learning, three dimensions of CoP are identified as mutual engagement, sense of joint enterprise, and a shared repertoire of communal resources and practices (Wenger, 2000).

PCoP is a type of CoP, which introduces theory and practices to practitioners. Its scope can move beyond organisational and sector boundaries, e.g. involving practitioners across the public, private and third sectors in a region (Clifton, Kyaw, et al., 2024; Liu et al., 2023; Walpole et al., 2022). Research suggests a PCoP can support practitioners to coproduce new processes and practices (De Laurentis et al., 2024) and support intra- and inter-organisational CoPs to coproduce new service solutions (Walpole et al., 2022). A PCoP offers a mechanism to facilitate the Triple Helix, meaning innovation through the interaction between university, industry and government (Liu et al., 2023), and support regional innovation through the creation of an innovation ecosystem (Clifton & Walpole, 2023). A recent study, based in South Africa, details the experiences of an emergent CoP which brought together stakeholders to co-create knowledge and to inform local policy and governance arrangements (Adelle et al., 2021).

The range of activities within CoPs (including PCoPs) develop a social learning space, where people 'care to make a difference' and yet they do not engage to persuade others to their point of view, as they are themselves prepared to have views changed or shaped (Wenger & Snyder, 2000) to enhance their learning. A key strength here is that learning occurs at the intersection of different practices, which can be seen as analogous to what occurs within regional innovation systems, albeit the latter at meso or macro level (Wenger & Snyder, 2000). Unlike formal groups or project teams, CoPs are largely self-organised around the shared passions and expertise that can help actors develop individual agency, rather than purely driven by top-down organisational or project needs (Gambarotto & Cammozzo, 2010; Liu et al., 2023; Walpole et al., 2022). Thus, CoPs promote knowledge sharing in the form of cultivation, rather than direction or regulation (Gambarotto & Cammozzo, 2010). The community persists as long as the commitment to do so remains, and they seek to build personal and organisational capability rather than necessarily delivering specific tasks or projects.

2.2.2. Innovation in CoPs

Nascent research (Liu et al., 2023; Smith et al., 2019; Walpole et al., 2022) suggests there is value in developing PCoPs, within formal development programmes, to enhance innovation capabilities and support practitioners to develop NSS. The efficacy of design thinking in developing NSS in collaboration with users and stakeholders has been established (Harhoff & Lakhani, 2016). However, limited formal programmes are available to firms that enhance the capabilities required to develop solutions to their current challenges (De Laurentis et al., 2024; Liu et al., 2023). Contemporary learning interventions aim to support participative pedagogies as proposed by Hodgson and Reynolds (2005) whereby the learner co-constructs the 'curriculum' and learning to ensure impact on the challenge they face within the workplace. Such a collaborative and participative approach relies on the dialogical creation of meaning and construction of knowledge (Hodgson & Watland, 2004). Transformative learning seeks to stimulate a learner's questioning of underlying assumptions and to restructure the way the learner sees the world and acts within it (Laros et al., 2017). In addition, to promote sustainability-focused and circular economy learning, recent literature suggests using digital technologies such as augmented and virtual reality to enhance experiential learning and design thinking process (Marcon & Sehnem, 2024; Earle & Leyva-de la Hiz, 2021). New ways of learning are also needed to create critical knowledge, enhance innovation, and engage with complex grand challenges e.g. sustainability (Elkjaer, 2022; Mailhot & Lachapelle, 2022; Van Rijnsoever et al., 2023). This requires further engagement with stakeholders and collaboration in the social world (Moratis & Melissen, 2022). Overall, the nascent literature referenced suggests CoP and PCoP can enhance the innovation capabilities of practitioners and facilitate shared learning and

knowledge sharing (Smith et al., 2019; Walpole et al., 2022; Wenger & Snyder, 2000). PCoP can support leadership development (Smith et al., 2019) and facilitate inter-organisational innovation to support regional innovation actors (Liu et al., 2023) and enable public service practitioners to deliver policy objectives (De Laurentis et al., 2024).

It is noted that organisational learning should encompass contemporary societal challenges such as sustainability (Elkjaer, 2022) and thus promote CE innovation across stakeholder networks (Moratis & Melissen, 2022). Several recent studies suggest that management education plays a significant role in supporting businesses to incorporate sustainability concepts, including helping businesses to design and implement solutions to tackle challenges such as waste management and decarbonisation (Van Rijnsuve et al., 2023; Moratis & Melissen, 2022). Indeed, through management education and learning, organisations can focus on sustainability-oriented innovation (Moratis & Melissen, 2022; Earle & Leyva-de la Hiz, 2021). For instance, organisations can learn the principles of CE and implement them to improve business performance (Clifton & Walpole, 2023; Liu et al., 2023). However, little empirical evidence exists on how a PCoP can enhance learning and develop innovation capabilities. Also, there is a paucity of understanding of the role of publicly funded programmes in supporting collaborative innovation (Franzò et al., 2023; West & Bogers, 2017).

3. Research context and Methodology

3.1. Research context

As set in Section 1, the research question is '*how can publicly* funded *Programme Communities of Practice enhance organisations' innovation capabilities*?' With an understanding of the link between innovation and economic growth, the Welsh Government has identified 'the percentage of businesses that are innovation active' as a national prosperity indicator in the Well-Being for Future Generations Act (Welsh Government, 2015). Through a competitive process, programmes aiming to enhance business innovation capabilities are financially supported. Thus, we selected Wales as the research context and engaged with two publicly funded PCoP in this region, the Developing Innovation Performance of Firms and Supply Chain Clusters (DIPFSCC) and the Open Innovation Community of Practice (OICoP).

Funded by the Welsh Government SMART Expertise initiative in 2019, DIPFSCC was a pilot programme to facilitate NPD and NSS and was delivered by two universities in Wales. The programme supported eight businesses to enhance their innovation capabilities to enable them to develop new products or service solutions to improve their productivity. OICoP, an iteration of DIPFSCC, was funded by Welsh Government in late 2019 with similar aims to facilitate knowledge sharing and enhance organisation innovation capabilites. OICoP supported thirteen participants from eight organisations and both PCoP lasted 9 months. Both PCoP were promoted by the host organisation and Welsh Government, raising awareness of the tools and knowledge that potentially facilitate innovation and sustainable development. Senior and middle managers attended the PCoP and recommending the programmes to their colleagues.

Fig. 1 outlines the structure of the PCoP, which delivered ten workshop days over nine months, designed for participants to learn with and from each other. The 'audit of practices' was a survey issued prior to the programme commencing, to obtain data on the innovation processes and practices of participants. The foundation day introduced participants to the programme content and objectives and introduce the CoP concept. A two-day residential event followed (a few weeks later) to form the participants into CoPs and introduce fundamental innovation dynamics models and reflective practice techniques (Gibb, 1988). The residential employed experiential group challenges that enabled the teaching of fundamental innovation models and the development of group collaborative

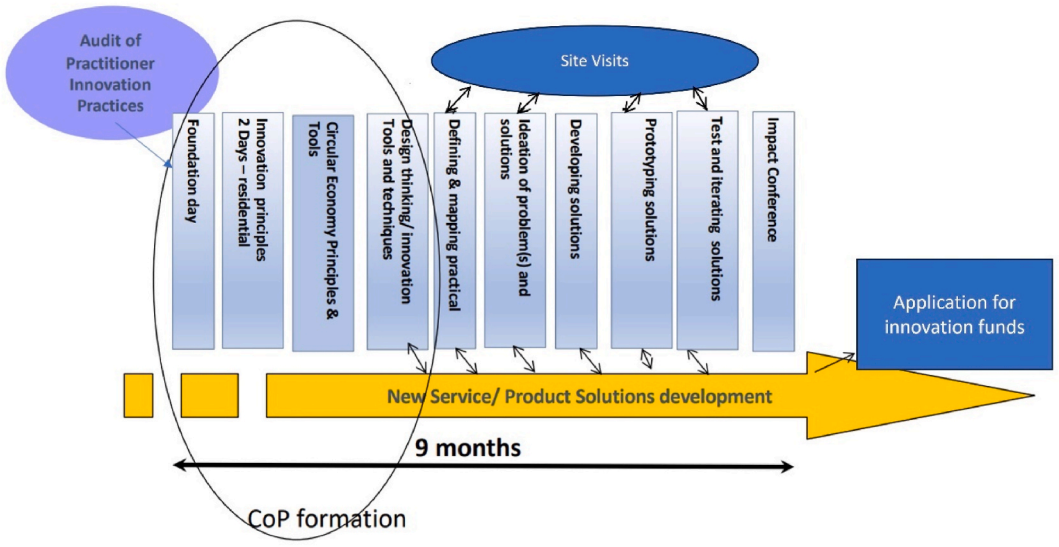

Fig. 1. Structure of the PCoPs.

working dynamics. Participants were encouraged to develop 'critical friend' relationships, explained in the first workshop. Participants' reflective practice capabilities were developed in group sessions after learning exercises and in pairs and triads at the beginning and end of each half day. The participants were also asked to choose one of three roles: community keeper, agenda activist or social reporter (Wenger-Trayner & Wenger-Trayner, 2020), during the residential, to manage their CoP. After the residential participants engaged with workshops spaced a month apart to develop their understanding of each phase of the design thinking process and for participants to apply the models learned, within the workshop, to their individual workplace challenge. The challenge-led design of the programme enabled participants to work on 'live' innovation projects as part of the programme. Participants were introduced to two or three innovation tools during each workshop to conduct the specific phase of the design thinking model during the subsequent month. Innovation tools included problem statements, stakeholder mapping, process mapping, complexity theory, PDCA (Plan-Do-Check-Act), ORID framework (Objective, Reflective, Interpretive, Decisional), 5 Why's, Action Learning Sets (ALS) and Business Model Canvas within the monthly one-day workshops.

Participants were also asked to consider CE tools e.g. the ReSOLVE (regenerate, share, optimise, loop, virtualise and exchange) framework (Ellen MacArthur, 2015) at each phase of their NSS development. Participants worked in groups in each workshop to critically reflect on their challenges and obtain feedback on progress. Their NSS were refined through site visits that provided insights to challenges, to see 'promising practices' and to engage with industry leaders and innovation experts. In addition, they received feedback from the university lecturers. The programme concluded with an 'impact conference' where participants presented their solutions and prototypes to organisational peers, invited academics, and policy makers. The participants were asked to draft short business cases which detailed the implementation and impact of their NSS, which could potentially be used to obtain funding to 'spread and scale' (this included a successful application for new machinery to Welsh Government). The presentations from participants detailed how they had applied their new skills and knowledge within their workplace challenge project.

The arrow on the bottom of Fig. 1 denotes the iterative development of participants' NSS/NPD project within each workshop, starting from defining challenges, idea generation, solution development, prototyping, and testing NSS/NPD (where possible) and capturing results for application funding (internal or external). Participants continued to engage within their CoPs beyond the PCoP, sharing knowledge and discussing challenges through 'WhatsApp' and a 'Linkedin' group. For instance, participants shared innovation and CE related articles and videos, updated each other on innovation project progress and organisation achievements through the network. Some participants presented their NSS to a seminar facilitated by the university. This has resulted in organisations applying for funds from UKRI (UK Research and Innovation) and Welsh Government SMART Expertise programme. The university PCoP organisers provided Research, Development and Innovation (R, D &I) support during the applications.

3.2. Method

This study uses the successful development and implementation of a NSS, by participants, that enhanced productivity, as a proxy for PCoP efficacy and enhanced organisational innovation capabilities. To answer the research question, we adopted a case study method to understand life-real phenomenon which are underexplored (Yin, 2018). Specifically, we engaged with eight participants of DIPFSCC and OICoP and obtained details of the NSS that they developed with the support of the PCoP. Table 1 provides an overview of the case studies. Although there are four (C1,2,4,6) from the same utility company, the innovation projects took place independently in different departments and were implemented by different PCoP participants.

Data collection involved semi-structured interviews conducted in 2020 after the completion of the PCoP with eight participants. Each interview lasted for approximately 1 h, resulting in a transcript of 6000 words on average. Interviews followed a protocol (Table 2) starting with broad questions, then specifically the participants' learning experience from the PCoP and the impact on their organisational innovation.

To capture data from various perspectives, an academic participant who organised and delivered the PCoP content was also

Table 1
Overview of the case studies.

Case	Industry Sector	Innovation Focus	CoP	Interviewee Position
Case 1 (C1)	Water supply and service	NSS	Open Innovation Community of Practice (OICoP)	Department manager
Case 2 (C2)	Water supply and service	Innovation Portal and stakeholder engagement	OICoP	Customer Service manager
Case 3 (C3)	Automotive production	Re-use of materials	OICoP	Senior engineer
Case 4 (C4)	Water supply and service	Process innovation	Developing Innovation Performance of Firms and Supply Scale Clusters (DIPFSCC)	Programme manager
Case 5 (C5)	Glass production	NPD	DIPFSCC	Commercial director
Case 6 (C6)	Water supply and service	Process innovation	OICoP	Technical delivery analyst
Case 7 (C7)	Textile producer	Sustainability-oriented innovation	OICoP	Production planning manager
Case 8 (C8)	Concrete producer	Materials and NPD	DIPFSCC	Production manager

Table 2
Interview protocol.

PCoP learning related questions:
- *When and why did you join the PCoP?*
- *What did you do in the first week?*
- *What did you do afterwards?*
- *What have you learnt so far from PCoP?*
- *When was the last time you engaged with PCoP? What happened?*
- *What did you enjoy the most?*
- *What could be improved?*
PCoP collaboration related questions:
- *Did you work with anyone from the PCoP, and in what way?*
- *Are you still working with them, and in what way?*
- *How do you keep contact with PCoP members?*
- *Does this result in any collaborated projects so far?*
- *Is there anyone from the PCoP you would like to work with in the future?*
Organizational innovation related questions:
- *What happened at your organisation due to your participation in the PCoP?*
- *What changed first?*
- *What are the achievements so far?*
- *What will be the next plan for this innovation project?*
- *Can you provide some specific examples?*
- *Does the changes involve external partners?*
Challenges related questions:
- *What are the challenges when implementing tools from the PCoP?*
- *What other support is needed?*

interviewed. Moreover, the research team also observed four workshops for each PCoP to understand the knowledge sharing and creation process and activities in the life-real context (Taylor et al., 2015), to ensures the robustness of the research and data triangulation (Yin, 2018).

All interviews were recorded, and transcripts were generated afterwards. We analysed the data with a three-level coding structure to ensure data transparency in qualitative research (Gioia et al., 2013). In the first stage, to avoid any potential researcher unconscious bias, each author developed initial codes independently through the reading and active engagement with the transcripts. Then collectively, the authors compared and discussed the results from the independent open coding to confirm the first-order concepts. In

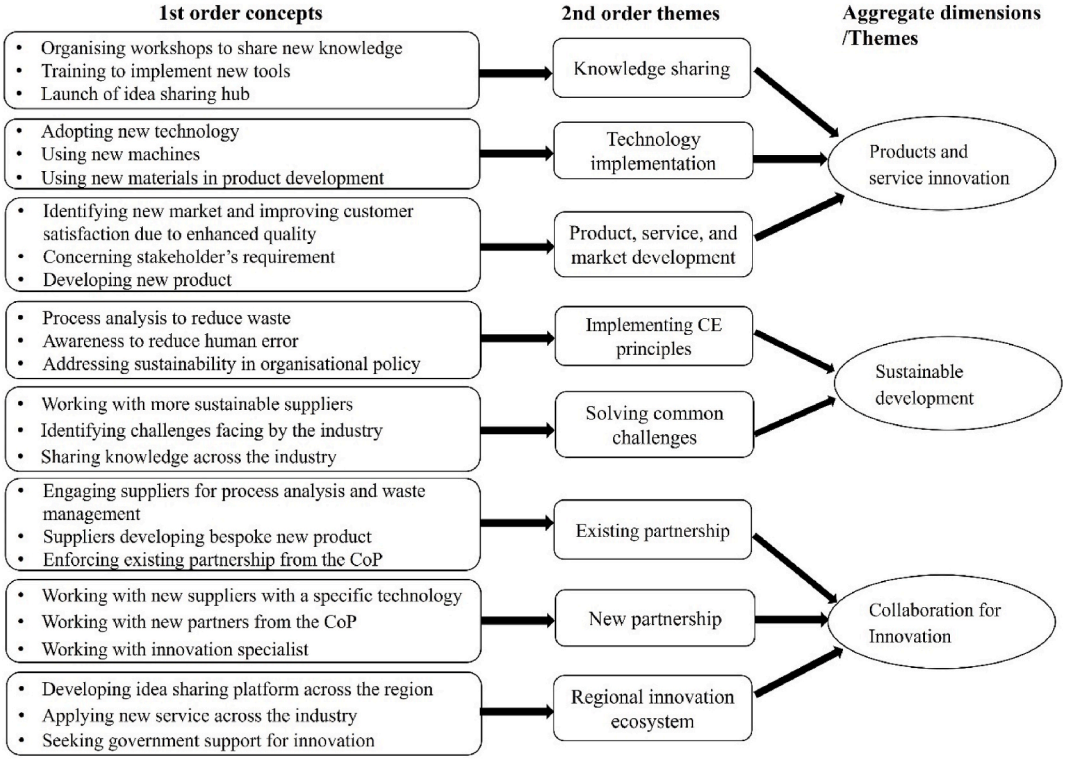

Fig. 2. Data structure.

the second stage, all authors worked together to develop second-order themes according to their similar patterns (Braun & Clarke, 2006). For instance, we grouped the first-order concepts 'developing idea sharing platform across the region', 'applying new service across the industry', and 'seeking government support for innovation' together into the second-order theme 'regional innovation ecosystem', as they represent a regional-based network of knowledge exchange and innovation that involved various business entities and government bodies. Similarly, the concepts 'process analysis to reduce waster', 'awareness to reduce human error', 'addressing sustainability in organisational policy' all indicate the pattern of reducing, reusing, and recycling, and hence were categorised as the theme adoption of the 'implementing CE principles'. In the final stage, all authors discuss the insights from the first two stages of data analysis, considering the theoretical connections with existing literature. This results in the identification of three aggregate dimensions/themes: 1) products and service innovation; 2) sustainable development; and 3) collaboration for innovation. Fig. 2 presents our data structure. Table 3 details the representative quotes from interview data which lead to the generation of 1st order concepts. Table 4 shows the representative examples of the second order themes.

Table 3
Representative quotes/examples leading to 1st order concepts.

Representative quotes	1st order concepts
• *"Inspired by the programme, we decided to create an online idea portal. We hope our staff can share any ideas and work on the ideas through this platform." – C2*	- Organising *workshops to share new knowledge (C2,4,6)*
• *"The process mapping part of the programme was fun … then we organised a meeting to use the tool to look at our processes and productivity." – C4*	- *Training to implement new tools (C2,4,7)*
• *"We now hold a meeting each week to share new ideas and talk about how we can improve things together." – C6*	- *Launch of idea sharing hub (C2,6)*
• *"I learned to engage staff differently, allowing people to contribute ideas. This has led to many small changes and improvements."* – C7	
• *"We started to apply bar-coded labels in our product. This turned out to be very efficient." – C1*	- Adopting *new technology (C1,3,8)*
• *"We've got real value from the tools and knowledge we've picked up from the DIPFSCC programme, we're really pleased with the cost savings and positive environmental impact resulting from the change to recycled plastic feedstock. The future impact will be huge as we will exponentially increase the number of parts that we print within the factory." – C3*	- *Using new machines (C3,5,8)*
• *"We've now reconsidered materials which are less costly and more durable in our products." – C5*	- *Using new materials in product dev*elopment (C3,5,8)
• *"Transforming toward Industrial 4.0, we have implemented new machines and utilised digital technologies."* – C8	
• *"The exercise really helped in understanding how to design solutions to problems from the customers' perspective. I believe customers are satisfied with our service." – C1*	- Identifying *new market and improving customer satisfaction due to enhanced quality (C1,8)*
• *"We consider the requirements from customers and broader stakeholders when delivering the service. Our relationship with customers has been improved because of this." – C2*	- *Concerning stakeholder's requirement (C2)*
• *"The new process helped us to develop a material to create our new product."* – C8	- *Develo*ping new product (C4, 8)
• *"By implementing the new solution, our downtime and human errors have reduced significantly. This also cut down the operating costs." – C2*	- Process *analysis to reduce waste (C3,5,7)*
• *"We've got real value from the University innovation programme; we're really pleased with the time, cost savings and positive environmental impact resulting from the new machine we were able to buy with Welsh Government support. The future impact will be huge as well. The tools and models I've picked up are being used by the innovation team in our monthly meetings, which bodes well for our future growth." – C5*	- *Awareness to reduce human error (C2,5)*
• *"Circular economy is a mindset change and behavioural change. For instance, where possible, we now use recyclable materials."* – C7	- Addressing sustainability in organisational policy (C2)
• *"Sustainability performance has become part of the criteria in our supplier selection process." – C3*	- Working with more sustainab*le suppliers (C3)*
• *"All water companies are facing the same challenges such as waste reduction, stakeholder relations. Thus, knowledge sharing is important." – C6*	- *Identifying challenges facing by the industry which is beyond a company project (C4,6)*
• *"The solution should be applied beyond a company project, so that in long term it can benefit the whole sector to be more sustainable."* – C6	- *Sharing* knowledge across the industry (C6)
• *"We soon applied the process mapping to our suppliers, who also conduct their own mapping to address waste reduction areas." – C3*	- Engaging suppliers for process analysis and waste management (C3,4,8)
• *"Our suppliers fully understood our needs including the sustainability requirement. So, they came up with a bespoke new product which was environmentally sustainable." – C4*	- Suppliers developing bespoke new product (C4)
• *"What we found was … by sharing ideas and knowledge, our relationship with the partners was enhanced."* – C8	- Enforcing existing partnership from the CoP (C8)
• *"Working with other companies with a completely different viewpoint, inspires us to work in a different way." – C1*	- Work*ing with new suppliers with a specific technology (C1)*
• *"We are talking about partnership with another company [to develop new products] which we would never have talked about before." – C3*	- *Working with new partners from the CoP (C3)*
• *"Our relationship with the programme participants continued. We don't want to stop here. In fact, we are initiating a new project with one participant."* – C4	- *Working with innovation specialis*t (C4)
• *"The university has been really helpful by organising the innovation programme and continuously supporting us with expertise." – C3*	- Deve*loping idea sharing platform across the region (C3)*
• *"Now our technology (camera) has gained recognition. Other water companies came to us and wanted to apply the same technology to their process. So, the impact could be across the whole sector." – C4*	- *Applying new service across the industry (C4)*
• *"We are applying for a SMARTCymru fund for the technical feasibility testing."* – C5	- *Seeking government support for in*novation (C5)

Table 4
Representative examples of 2nd order themes.

Representative examples	2nd order concepts
• *C2 launched an online platform 'Idea Portal' with the aim of sharing knowledge and advancing innovation within the organisation.*	Knowledge sharing
• *C4 involved supply chain partners to share knowledge and best practices.*	
• *C7 carried out workshops within the organisation to provide recycling and waste management related trainings.*	
• *C1 implemented a new process for labelling petri dishes, which improved their productivity.*	Technology implementation
• *C5 implemented a new machine with advanced technologies for glass manufacturing which can reduce the production time and better meet the market requirement.*	
• *C8 developed a new material to create a product that was reading for testing.*	
• *C2 gathered feedback from stakeholders and incorporated this in their new product development.*	Product, service, and market development
• *C4 develop a new digital camera for pipe internal condition assessment, which represents a significant degree of service innovation.*	
• *C8 identified a new market of their ancillary products and focused on the improvement of the product quality.*	
• *C2 addressed the importance of sustainability* e.g. *recycling, ethical sourcing, in their organisational policies.*	Implementing CE principles
• *C3 switched the printer feedstock from virgin to recycled plastic. They also explored how plastic as packaging can be repurposed into 3D printer feedstock.*	
• *C5 implemented continuous improvement tools to reduce human errors in their operations.*	
• *C3 worked with more sustainable suppliers to better manage waste across the supply chains.*	Solving common challenges
• *C4 involved partners to analyse the root reasons causing problems in the supply chains.*	
• *C6 worked on common challenges facing by all water companies* e.g. *(how to deal with waste reduction) and accordingly seeking for new solutions.*	
• *C3 applied its new process mapping tools to their suppliers who are existing partner. These partners then conduct their own mapping to address waste reduction areas*	Existing partnership
• *C4 asked their existing suppliers to develop bespoke new service in monitoring water quality.*	
• *C8 strengthen the relationships with their existing partners (a major paving supplier) who also joined the CoP.*	
• *C1 actively approached other companies from the CoP and explored the collaboration opportunities. They formed new relations based on the CoP.*	New partnership
• *C3 enjoyed the knowledge co-creation with CoP participants. They continuously worked with new partners through online platform.*	
• *C4 worked with new partners, innovation specialists who can help advance their camera technologies.*	
• *C3 launched an online platform for knowledge sharing across business in Wales.*	Regional innovation ecosystem
• *C4 developed an innovative water quality mornitoring solution with the aim of promoting this to the entire water industry in Wales.*	
• *C5 approached local universities and government to advance their service innovation. The collaboration with these innovative actors helps form a reginal innovation ecosystem.*	

4. Findings

4.1. Case 1

The innovation focus of Case 1 was new service solution development, specifically the improvement of the water quality testing within the organisation's microbiology laboratory. Here, Interviewee 1 was an department manager from a water company participating in OICoP. After participating the CoP, Interviewee 1 ran a series of process mapping sessions in the lab. This led to quick wins in terms of reducing waste and improving productivity. An example was a new process for labelling petri dishes. The revised process has saved a team of 5 people approximately 30 min per day per person, and enabled colleagues to feel satisfied and motivated on seeing the solution they had generated delivering real productivity gains. This gave the team confidence to use the innovation tools introduced by OICoP and motivated them to look at other areas to apply their newly learnt skills.

There are both economic and environmental impact benefits from these NSS. A project is in progress to use bar-codes which will also improve the process for uploading results of analysis. It is estimated that this new process will save approximately 1-h per day per team member (5 h per day for the 5-person team). Thus, total time savings are around 37.5 h per week, with estimated cost savings of approximately £60,000 per year. Additional productivity gains are improved quality with fewer samples having to be recalled and re-tested (currently 100 samples per annum need to be re-tested due to labelling errors), reputational gains, improved customer satisfaction, and lower carbon footprint.

4.2. Case 2

In Case 2, the innovation focus was on an Innovation Portal and stakeholder engagement, specifically the continuous improvement in the water company's retail customer service department. Interviewee 2 is a customer service manager. After participating in the OICoP, Interviewee 2 ran an 'away day' to introduce the human-centred design methods and tools. As a result, the team now uses the method to gather stakeholder views for the internal customer projects they deliver. According to Interviewee 2, OICoP was the catalyst that led to the launch of the organisation's online 'Ideas Portal', which allowed members of staff to put forward their ideas. The Continuous Improvement team uses tools and methods from OICoP to prioritise ideas to take forward and then works with the idea generator to create NSS. The portal has already received over 300 ideas, with approximately 10 new ideas added each week.

The innovation impact is mainly economic benefits, with process improvement gains within existing organisational processes. One project achieved a £7500 cost saving; obtained from a relatively simple change to the organisation's data protection policy and practice which allowed data to be provided from more than one source. As a result, call centre staff were able to reduce repeat contact with

customers, freeing resources to deal with other queries. The success of the trial within the retail section (approximately five hundred staff) has led to it being rolled out across other departments, increasing the opportunities for cost savings and process improvements.

4.3. Case 3

In Case 3, the innovation focus was on developing an Innovation Lab and internal stakeholder engagement process within an engine plant of a large automotive company. Here, Interviewee 3 was a Senior Emerging Technologies Engineer who attended DIPFSCC. Based on the learning, he initiated an innovation project on the re-use of materials. Inspired by the knowledge learnt at the PCoP, Interviewee 3 and the team applied CE principles to the printing of plastic parts, looking at the material that was being used by the 3D printers in the factory and liaising with the filament suppliers. The organisation was able to switch the printer feedstock from virgin to recycled plastic. They also explored if the plastic that comes into the factory as packaging can be repurposed into 3D printer feedstock. In addition, the innovation team further developed their Innovation Lab to connect their open innovation programme with other businesses across the region, promoted by its European Headquarters.

The innovation impact includes both economic and environmental benefits; 3D printers previously used around 8 kg per month of virgin plastic each, saving approximately £18 per kilo and carbon footprint savings from using recycled filament. Thus, applying CE principles has had a positive economic impact and averts hundreds of kilos of plastic waste from landfill, contributing to environmental sustainability.

4.4. Case 4

Case 4 concerns process innovation. In this case, Interviewee 4 is a programme manager for a water company, w]\orking within the capital projects division. Interviewee 4 applied learning from DIPFSCC and initiated a project that looked at challenges with their pipe internal condition assessment processes. The manager brought together the entire supply chain involved in the camera surveying of pipes (capital works partner, the standpipe and hydrant/valve manufacturer, the camera-survey equipment supplier and the operator) at the hydrant manufacturer's site, to map the entire process involved in using the cameras, drawing on tools from the project. Once mapped, the team observed the task being conducted to carry out root-cause analysis of the problems encountered. The root-cause analysis brainstorm session, with all the partners, developed NSS and products that would address current problems.

The innovation process resulted in a NSS that had a positive financial impact. The camera supplier now conducts the surveying themselves in order to achieve better results in producing 'in pipe' images and provides training for the capital partner on better use of the camera equipment. The NPD solutions included: the manufacturer making the standpipe with a larger diameter tap to allow different hydrant modes; the camera manufacture removing some of the functionality and superfluous elements of the camera to reduce its size, which in turn increases its user-bility; the hydrant manufacturer provided bespoke transparent hydrants to understand the movement of the camera during the operation. Based on the above actions there is the potential to make savings of several million pounds in the next 3 years, through fewer exploratory excavations.

4.5. Case 5

The innovation focus of Case 5 is NSS. The organisation is a glass factory which provides a bespoke glass and glazing service for both commercial and domestic clients. Interviewee 5 is a Commercial Director of the factory who participated in DIPSFSCC. Tools introduced by DIPSFSCC have been used to develop NPD internal processes including on a project for a large hotel chain that required hundreds of painted glass screens and decorative pieces in a short space of time. Using the process mapping skills, the organisation discovered that the bottleneck in their process was the drying time required for painted glass, which causes issues with their customers and storage issues within the factory. The approximate production time for each piece was two days. With market research, the innovation team discovered that a machine was available that could reduce the production time of each piece to approximately 2 h. The machine in question was expensive and so DIPSFSCC referred Case 5 organisation to a Welsh Government innovation specialist who then supported the organisation to successfully make an application to the SMARTCymru innovation fund.

The impact of the NSS innovation has reduced cost and carbon footprint. With the recently installed machine, production time has indeed been reduced from two days to 2 h, increasing the capacity to deliver to customers. The machine also uses less paint and so creates considerable environmental benefit. The new machine has also reduced their energy consumption.

4.6. Case 6

Case 6 describes process innovation at a water company. The innovation was led by Interviewee 6, a Technical Delivery Analyst who participated in OICoP. From the PCoP, Interviewee 6 learned the ALS approach to address some of the common issues that arise in workshops where participants want to offer advice or 'solutionise' before getting to a real understanding of the issue. The skills and knowledge allowed Interviewee 6 to steer colleagues away from jumping to solutions and helped to ensure that all attendees were able to contribute. Taking part in OICoP enabled him to facilitate a workshop with increased confidence in applying the ALS method. In addition, he created a knowledge bank of innovation practices to share within the organisation, as well as writing up examples of how tools and knowledge have been used in practice, and reflections on these.

The impact of the process innovation, i.e. use of the ALS, can be seen at the organisational and stakeholder levels. It has allowed for the negotiation of 'dominant' voices and fostered interest organisational processes. As a result, Interviewee 6 helped the organisation

deliver a co-created solution that was community validated. The workshop facilitated by Interviewee 6 broadened the perspectives of colleagues beyond the original problem owners to include other stakeholders, which has led to a more effective solution.

4.7. Case 7

Case 7 concerns sustainability innovation at a textile factory. Interviewee 7 is a textile designer and production manager. She attended OICoP, during which she examined how waste from the woollen mill could be repurposed, with the firm keen to focus on outcomes that could benefit the business (thus re-use being the priority). Following her participation the CoP, Interviewee 7 carried out a 'brainstorming' session with managers at the mill to look at issues around sustainability, using the ORID framework from the CoP. The first 'easy win' was to ramp up recycling and waste segregation across the whole business, covering the shop, café and mill site. This was in the process of being implemented when COVID19 restrictions meant that the business had to re-focus on the response to the pandemic, ensuring sales could continue and the business survive. After the lockdown, the project was resumed and the organisation ordered recycling bins for use throughout the business.

The innovation activities have made the respondent think differently about sustainability and understand it in terms of cost reduction, business and marketing opportunities. Interviewee 7 is now the sustainability lead in the company and will be looking at this in terms of impact on the environment and the longevity of the business. A next step is to 'recruit' others within the business that are interested in innovation and sustainability to work together to move these ideas forward.

4.8. Case 8

In Case 8, the innovation focus is NPD. Interviewee 8 is a Production Manager from a concrete producer, who attended DIPFSCC. The company had existing links with a major paving supplier but had not taken forward any development opportunities with them. Participating in DIPFSCC allowed the two companies to systemise R&D capability and work through the design and market challenges. Subsequently, Case 8 company worked on the NPD process, identifying the main steps such as materials testing requirements; market and competitor analysis; and IP requirements. The NPD process also enabled the company to identify skills and knowledge requirements. Specification for the technical and commercial feasibility of a new product was developed which incorporated waste materials to create a more durable and flexible material.

The impact of the innovation is largely economic. The innovation activity helped to build trust and communication between the company and their suppliers. The process culminated in the development of a material to create a product (a trief safety kerb for use on

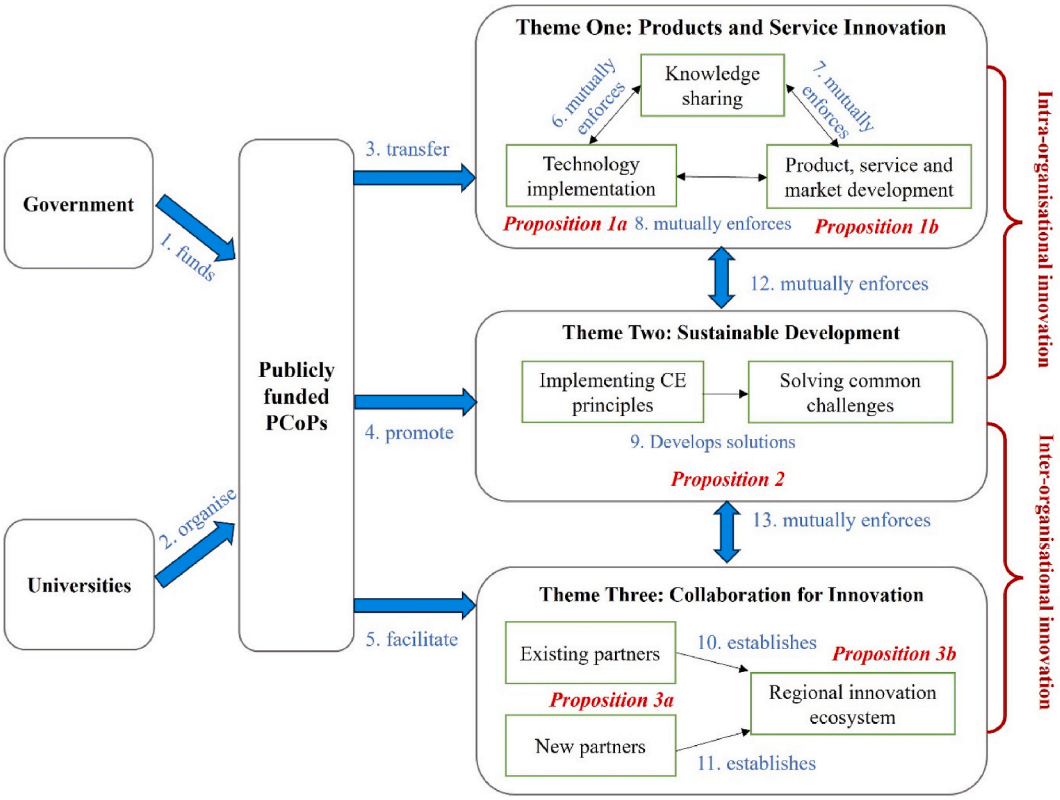

Fig. 3. A model to link PCoP to innovation.

motorways) that is ready for testing, and an application to SMARTCymru for technical feasibility test funding. The intention is that the material would be produced by the smaller caste study firm with production and installation undertaken by the larger highways contractor. Further, ancillary products have been identified (railway sleepers, prefabricated building materials) which have a mass market, and both companies now have the capability to work through the NPD process to create these and to develop future potential refinements of the material. Both companies stated that the project had been invaluable in bringing together disparate ideas and highlighting that partnership working enables more robust solutions.

5. Discussion

5.1. Thematic analysis and proposition

Following the three steps of coding defined by Gioia et al. (2013), as described in Section 3, our data structure is presented as Fig. 2. Eventually, three main themes were identified: 1) products and service innovation; 2) sustainable development; and 3) collaboration for innovation. Further, we explore the insights of each theme and explore the relations between the themes which include temporal sequences, boundaries within and across organisations, and causes and effects. Accordingly, we generate Proposition 1a and 1b under Theme One, Proposition 2 under Theme Two, and Proposition 3a and 3b under Theme Three. These indicate that PCoP can positively contribute to innovation and sustainable development. Furthermore, a framework is developed to connect all the themes, as shown in Fig. 3.

5.1.1. Theme One: products and service innovation

The first theme concerns the value of participating in a PCoP to the new product and service solution development process in the participating organisation. Evidence (Table 3) includes the sharing of new tools, ideas across the organisation either through workshops, events, informal forums, or the establishment of innovation hubs. In particular, technology implementation has led to, operational improvement and cost reduction. Thus, under Theme One, we propose Proposition 1a.

Proposition 1a. *Through attending publicly funded PCoPs, practitioners can bring new tools and technologies to the organisation, promoting the sharing of ideas, knowledge, and good practice across the organisation. PCoPs can improve operational efficiency, resulting in better product and service delivery.*

Moreover, PCoP have introduced digital tools, which have been adopted by the case companies. This results in operational efficiency and the development of new products and services. For instance, the product might use an advanced digital camera, bar codes, while services can provide better connectivity with suppliers and customers through digital platforms. Thus, another proposition can be generated, as follows.

Proposition 1b. *Through attending a publicly funded PCoP, practitioners can learn and adopt digital technologies to their organisation, and thereby change processes and improve product and service design. Thus, PCoP can lead to technological, product and service innovation in the organisations.*

Proposition 1a is linked to organisational level innovation capabilities and indicates that PCoP can advance R&D activities (Steinmo et al., 2022), open innovation (Chesbrough, 2023), and cross functional collaboration within an organisation (Moaniba et al., 2018) and region (Schiller, 2011). In particular, the cases show that inbound open innovation activities (Chesbrough, 2003; Chesbrough & Brunswicker, 2014) in the form of a PCoP can transfer ideas, knowledge and skills to participating organisations effectively. Whilst current innovation capability literature mainly focuses on organisation's engagement with customers and suppliers (Chesbrough, 2003; Dodgson et al., 2006; Laursen & Salter, 2004) for inbound open innovation activities, our findings highlight the role of PCoP, which are beyond the scope of direct industry partners. Proposition 1b concerns the impact of a PCoP on the market side (Aas & Breunig, 2017) to develop innovation capabilities. This also chimes with the recent management education literature that affirms the positive role of digital technologies in promoting sustainability-oriented learning and design thinking processes (Marcon & Sehnem, 2024; Earle & Leyva-de la Hiz, 2021), and more importantly the scope of technology application is extended from conventional formal education to informal PCoP. Overall, proposition 1a and 1b indicate PCoP positive role in developing innovation capabilities and mobilising changes within an organisation (Clifton, Kyaw, et al., 2024; Swan et al., 2002).

5.1.2. Theme Two: sustainable development

The data suggests changes in daily practice have also led to the development of new products and service solutions with increasing attention on sustainability, see Table 3. Accordingly, organisations have implemented circular economy principles in waste management, training, and product and service development. Furthermore, findings reveal the possibility of large-scale innovation to tackle grand challenges in a whole sector or across a region, e.g., reducing carbon footprint. This is due to developing awareness of sustainability and CE, emphasised by the PCoP. The PCoP also serves to build a common vision, trust, communication and cross-industry networks, which can facilitate the development of solutions to grand challenges. The impact of PCoP on sustainable development through the promoting of CE concepts is emphasised by the PCoP organiser as, "*Programme participants were introduced to linear economy and circular economy definitions and exposed to Ellen MacArthur video content. Participants were set a challenge, which had to be completed in groups, where each group could not complete their task unless they shared materials, which was designed to teach CE principles. The programme explained the ReSOLVE framework and asked participants to outline where their NSS incorporated elements of the framework, with most participants detailing any carbon footprint savings within their final presentations.*" Accordingly, under Theme Two, the following

proposition can be developed.

Proposition 2. *Through the facilitation of the PCoP, participants can implement circular economy and sustainability related principles in their process, product and service development. Through developing trust, common vision and networks, they can jointly tackle sustainability related challenges. Thus, PCoP can promote sustainable development.*

enun_Proposition_1Proposition 2 *extends the motivation of outbound open innovation, a crucial factor of innovation capabilities, from commercialisation-oriented technology transfer* (Danneels & Frattini, 2018; Piller & Walcher, 2006) *to sustainability and CE transition* (Clifton & Walpole, 2023). *It also indicates the possibilities of PCoP influencing the development of transformative innovation policy, and thereby helping businesses collectively tackle grand challenges* (Adelle et al., 2021; Borges et al., 2017; Foxon & Pearson, 2008; Haddad et al., 2022; Raven & Walrave, 2020; Schot & Steinmueller, 2018) *e.g., to transition to a CE at organisational, sector and regional levels* (Clifton et al., 2024; Clifton & Walpole, 2023). *This affirms the assertions of recent studies that CE innovation relies on collaboration, including direct supply chain partners, and wider stakeholders, within which collective learning is essential* (De Laurentis et al., 2024; Liu et al., 2024)

5.1.3. Theme Three: collaboration for innovation

The third theme is the enhancement of inter-organisational innovation capabilities. Our data (Table 3) shows that participating businesses collaborate with supply chain partners to apply the knowledge and tools learnt from the PCoP. Through participating in the PCoP, organisations build new partnerships through the connections established between participants, which can facilitate innovation projects. Thus, a proposition can be generated as follows.

Proposition 3a. *Through publicly funded PCoPs, participants can enhance collaboration with existing partners, as well as develop new inter-organisational partnerships, which can help their organisations identify innovation opportunities.*

The evidence also shows that collaboration is extended from direct supply chain partners towards wider contacts, and networks can develop at a regional level, where university, government, and industry are involved to share expertise and co-create knowledge. Accordingly, another proposition is developed as follows.

Proposition 3b. *Through publicly funded PCoP, participants can develop wider connections with industry, university and regional government to exchange and co-create knowledge. Thus, PCoP can positively promote a regional innovation ecosystem.*

Proposition 3a and 3b further highlight the importance of external collaboration to an organisation's innovation capability (Kathoefer and Leker, 2012). These inter-organisational innovation capabilities enhance organisational innovation capabilities. In particular, the study demonstrates PCoP can effectively foster a creative culture (Lounsbury et al., 2018), cross-functional collaboration (Moaniba et al., 2018) and support the development of innovation processes (Urbinati et al., 2022). The case study data suggests PCoP create a new form of open innovation, which is different to existing joint ventures, alliances and consortia innovation mechanisms (Chesbrough & Brunswicker, 2014) and yet effective in enhancing inter-organisational innovation capabilities. This study shows that PCoP can facilitate collaboration across sectors in an informal self-organised format (Wenger & Snyder, 2000), unlike more formal joint ventures, alliances and consortia that can facilitate innovation. This study contributes to the nascent literature on new and more nuanced forms of innovation collaboration, such as networks, PCoP, ecosystems and online platforms (Knoch, 2022; West & Bogers, 2017). Our findings also confirm that CoP are based on passion for a domain and thirst for knowledge sharing (Adelle et al., 2021; Liu et al., 2023; Walpole et al., 2022), through which organisations can share best practice and seek opportunities to further advance innovation jointly. Moreover, the propositions are based on empirical evidence and support the argument that knowledge sharing within a CoP can be extended to broad network-based learning and innovation (Knoch, 2022; Swan et al., 2002), as the case study participants identified and collaborated with new partners. In the medium term, PCoP can play a facilitating role in realising effective Triple Helix (Etzkowitz, 2008) networks of university, government, and industry to create effective regional innovation ecosystems (Liu et al., 2023).

5.2. Towards a process framework of PCoP

5.2.1. Publicly funded PCoPs

To elaborate on the connection between the core themes of Theme One, Theme Two, Theme Three, and the second-order themes, a framework is developed and presented in Fig. 3. For the purpose of illustrating clearly the interactions between the constructs of Fig. 3, we number each specific relationship as Arrow 1, Arrow 3, …, Arrow 13. For instance, Arrow 1 represents the relationship between government and publicly funded PCoP. It shows that government 'funds' PCoP. The framework also considers the wider scope of an innovation ecosystem containing university, government, and industry, where a PCoP is situated.

The left side of Fig. 3 represents the sources of funds for the PCoP. The PCoP is funded by the *government* (see Arrow 1), and it is led and organised by key regional stakeholder *universities,* who approach potential participants, design and content in the programme, and form the PCoP (Arrow 2).

5.2.2. Three themes

The middle of the framework shows the operations of the PCoP, which have a positive impact on the three themes: product and service innovation, collaboration for innovation, and sustainable development. As the data analysis reveals, first, PCoP can transfer new knowledge, tools, technologies to business participants and their organisation, leading to **products and service innovation**

(Arrow 3). Second, PCoP promote the concept of CE among the business participants, which results in **sustainable development** in the participants' organisations (Arrow 4). Third, PCoP facilitate collaboration among the business participants and a wider regional innovation ecosystem by connecting them together through group tasks and organising networking events, which results in **collaboration for innovation** (Arrow 5).

Inside Theme One, product and service innovation, *knowledge sharing* mechanisms e.g., trainings, workshops, innovation hubs to advance learning and augment the process. This results in *technology implementation* such as digital tools and process improvement (Arrow 6) and the accumulation of new product related knowledge (Arrow 7). The technology implementation experience can be further shared as new knowledge (Arrow 6). Technology implementation can result in better R&D and *product, service and market development* (Arrow 8), whereas the continuous improvement of these products drives technology advancement (Arrow 8). Moreover, technology, product and service development can enrich the resources in innovation hubs, thus implementing *knowledge sharing* (Arrow 7). Consequently, the three sub-themes of Theme One (knowledge sharing, technology implementation, and product, service and market development) are mutually enforcing (Arrow 6,7,8).

Inside Theme Two, sustainable development, organisations practise and implement CE principles learned within the PCoP. As shown in Fig. 3 (Arrow 9), CE principles implementation can further develop *solutions to common challenges*. Particularly, implementing CE principles (e.g., share, lease, reuse, repair, refurbish, and recycle) can help curb waste generation, reduce greenhouse gas emissions, and improve resource efficiency across various industrial sectors. The reusing and repairing of materials can extend product lifespans, and hence can reduce demand for virgin inputs. Though waste management, waste is diverted from landfills to extract and recover those valuable materials. Thus, common challenges such as climate change and material shortage are effectively addressed through CE practices.

Theme Three outlines, collaborating for innovation. Through participating in a PCoP, organisations share new process and promising practices with their *existing partners* and suppliers. Furthermore, PCoP help organisations to identify the opportunities of working with other participants, and thus form *new partnerships*. Based on these partnerships, various organisations can connect with each other, disseminate knowledge, and initiate innovation projects, and thus in the medium-term establish a regional innovation ecosystem (Arrow 10,11).

It is noted that the implementation of CE principles rely on new product, service and business models such as sharing resources (Arrow 12). Alternatively, innovation projects are inspired by CE principles such as using greener technologies (Arrow 12). Moreover, product and service innovation increasingly require inter-organisational collaboration (Arrow 13). Such collaboration can also promote CE transition across sectors and regions (Arrow 13). Thus, a mutually reinforcing relationship exists between Theme One, Theme Two, and Theme Three (Arrow 12, 13).

5.2.3. Intra-organisational and inter-organisational innovation

Finally, the right side of the framework shows the levels of the innovation, as affected by PCoP, which includes intra-organisational and inter-organisational levels. It is evident from our study that process innovation and NPD/SS innovation takes place inside an organisation, namely intra-organisational. The data suggests the knowledge and tools learned within the PCoP are transferred into participants organisations through group innovation projects and continuous improvement initiatives.

Similarly, at an intra-organisational level, organisations implement CE principles through internal process improvement and waste management projects. This confirms findings from a recent study indicating CE transformation starts with internal projects (Liu et al., 2024). Nevertheless, the tackling of common challenges requires wider collaboration between industry, government and universities. Therefore, the development of sustainable practices to transition to a circular economy requires a both intra-organisational and inter-organisational innovation.

Inter-organisational collaboration for innovation is shown at the bottom-right of Fig. 3. The active engagement with supply chain partners and local communities can further promote CE innovation and sustainable development (Liu et al., 2024). Our findings highlight the important role of PCoP in the transition to a circular economy. Moreover, it is evidence that PCoP facilitate knowledge creation and diffusion at a regional level through the formation of collaborative networks (Knoch, 2022; Liu et al., 2023; West & Bogers, 2017). Accordingly, PCoP can effectively support regional innovation ecosystem (Clifton & Walpole, 2023).

Our framework identifies important elements within innovation and their linkages. It also provides a holistic view of how a PCoP can create connections between participants, with their organisational colleagues and processes, government and university. We thus, highlight the significant role that a PCoP can play in the regional innovation system and the transition to a CE. In addition, we highlight the intermediate role of learning in the form of intra-organisational and inter-organisational knowledge sharing, which is facilitated by PCoP. Indeed, organisational learning is a means to enhance organisational performance (Elkjaer, 2022) which also includes developing sustainable practices. Thus, the framework also identifies interaction with and among stakeholders, which is deemed increasingly important in sustainability-oriented learning (Moratis & Melissen, 2022).

6. Conclusion

To enhance innovation capabilities and tackle sustainability related challenges, practitioners and researchers have responsibility for the development of relevant and critical knowledge (Elkjaer, 2022; Mailhot & Lachapelle, 2022). While extant literature focuses on the role of CoP and PCoP in collective learning and leadership development, our study explores how publicly funded PCoP enhance innovation activities at the organisational and inter-organisational level, which in turn develops organisational innovation capabilities and sustainability performance. Through engaging with two PCoP in Wales and drafting eight case studies, we have identified three important themes and generated key propositions. Findings reveal, firstly, that PCoP can facilitate the learning of new tools, processes,

and technologies to support product and service innovation. Secondly, PCoP can promote innovative solutions to common challenges, such as implementing circular economy principles. Thirdly PCoP facilitate collaborative inter-organisation innovation. Moreover, our framework (Fig. 3) addresses the theoretical gaps in terms of the connection between PCoP and innovation outcomes, particularly via the innovation capabilities approach which can be used to gauge the success of the PCoP intervention. Our paper answers a recent call for empirical research that contributes to the understanding of how publicly funded collaborative projects can support businesses to develop innovation capabilities (Franzò et al., 2023). It also advances the understanding of the role of PCoP in management education, and innovation in response to grand challenges (Mailhot & Lachapelle, 2022; Moratis & Melissen, 2022; Earle & Leyva-de la Hiz, 2021).

Our paper has practical implications, as the evidence indicates that university-designed publicly funded PCoP can effectively promote innovation activities at organisational and regional levels. Thus, such programmes have developed a 'blueprint' for guiding how businesses in Wales, across the UK and beyond can work collaboratively with regional universities to share risk, knowledge, and grow the future of industrial R&D focused on delivering the essential transition to a CE and clean growth outcomes. Policy makers should be inspired by this study to support PCoP within and across sectors to encourage organisations to work within regional innovation ecosystems to enhance regional productivity and support the transition to a CE.

There are limitations to the study, which also provide directions for future research.Our findings provide a comprehensive set of factors that facilitate innovation and sustainable development. Future studies can test the proposed framework (Fig. 3) and explore details of specific factors e.g. collaboration for innovation in the context of PCoP. The evidence presented on how regional innovation ecosystems can be supported through the collaboration of government, universities and organisations by establishing a PCoP is a valuable contribution to the management education and innovation literature. The study relies on the engagement with two PCoP, both located in Wales. Further research within different regions of the UK (and EU) would enable the study findings to be tested for generalisability. Additionally, investigations that consider different types of PCoP, for instance in different sectors and subject areas. Our case studies demonstrates that the PCoP approach can lead to improved innovative outcomes, yet like most interventions it is difficult to evaluate within relatively short timelines. In this paper, we focus on short-term innovation capabilities i.e. increased collaboration, and new product development capability development. In the medium term, there is a need to develop a comprehensive set of indicators to measure the impact of PCoP. Moreover, further research that focuses on the pedagogy aspects of the PCoP, should reveal antecedents to their relative success.

CRediT authorship contribution statement

Gary Walpole: Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Zheng Liu:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nick Clifton v:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Songdi Li:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Conceptualization.

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Data availability

Data will be made available on request.

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