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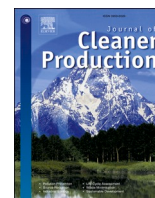
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Uncovering the role of the industrial symbiosis facilitator in literature and practice in Nordic countries: An action-skill framework

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ABSTRACT

As a collective approach for achieving economic, environmental, and social effects, industrial symbiosis is considered an important tool to realize a circular economy. In both literature and practice, the need for a third party facilitating the development of these resource exchanges between companies has been highlighted. This paper explores the actions and skills needed for achieving successful facilitation of industrial symbiosis by unfolding the facilitator role. It develops an analytical action-skill framework by systematically examining the relevant literature and conducting an in-depth analysis of a Danish facilitation team, and tests the developed action-skill framework by analyzing experiences obtained from seven facilitators in Nordic countries. In doing so, the study reveals a variety of actions of the industrial symbiosis facilitator that can be identified across literature and practice, belonging to five overarching tasks: Developing linkages, coordinating, capacity & knowledge management, value assessment & distribution, and developing beneficial conditions & scaling up. The results indicate that we observe a role in the process of homogenization. Another contribution is the uncovering of industrial symbiosis facilitator skills. The paper points to five overarching skills that are relevant to the facilitator role: Social skills, work approach, motivation & interest, ethics & responsibility, and knowledge. Subsequently, eight specific tensions between the identified actions are discussed. These make the role of the industrial symbiosis facilitator skill demanding and context-dependent and show an additional, implicit skillset.

1. Introduction

As the global economy is facing a need to economize on resources and mitigate emissions from human activities, *industrial symbiosis* is becoming increasingly important. Industrial symbiosis (IS) is a collective approach by which two or more organizations exchange, share, or transact excess resources, such as by-products or waste, in a systematic way to reduce the consumption of virgin material, energy inputs, and the generation of waste and emissions (Chertow, 2000; Sokka et al., 2011). In recent years, the concept has received increased attention in research (Mallawaarachchi et al., 2020; Vahidzadeh et al., 2021). Industrial symbiosis is widespread in Asia, North America, and Europe, but cases can also be found in Oceania, North Africa, and South America (Neves et al., 2020), for example in Brazil (Sellitto et al., 2021). European examples include practices in the UK (Mirata, 2004; Paquin and Howard-Grenville, 2012), the Netherlands (Baas and Boons, 2004;

Spekkink, 2013), Portugal (Costa and Ferrão, 2010), Sweden (Lindfors et al., 2020), and Denmark (Valentine, 2016).

What characterizes these European examples is that they to a great extent come about through facilitation by an entity other than the symbiotic organizations (Doménech et al., 2019). Essentially, IS networks come about in three ways (Boons et al., 2017), i.e. as planned top-down (Behera et al., 2012), emerging bottom-up (Baas, 2011), or combinations thereof, where planned and self-organizing elements are combined (Costa and Ferrão, 2010). Facilitation is a predominant method of the latter approach (Park et al., 2018).

Facilitation refers to helping a group of actors to achieve a common goal and assisting them in obtaining desired results and outcomes through mediating frameworks and dialogue (Andersen et al., 2018). Being critical to the success of IS (Belaud et al., 2017; Bøllingtoft et al., 2012; Lombardi, 2017; Morales and Diemer, 2019), facilitation may involve various elements (Sommer, 2020; Lindfors et al., 2020), such as

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brokerage, collective learning, pilot facilitation, and dissemination (Boons et al., 2017). Actors conducting and shaping facilitation have been called many names, for instance “champions”, (Hewes and Lyons, 2008; Kokoulina et al., 2018), “network orchestrators” (Paquin and Howard-Grenville, 2013), “designers” (Lawal et al., 2021), and “symbiotic agents” (Agudo et al., 2022). Facilitation may be driven by public or private organizations, each of which present its own advantages and disadvantages (Södergren and Palm, 2021).

Even though IS facilitation and the dynamics driving it have been studied for a decade, there has been limited focus on the actions and skills that characterize the role of the IS facilitator. Previous studies show that the facilitator’s skills are important for IS facilitation (Mortensen and Kørnøv, 2019). We argue that a deeper insight into the phenomenon is required as a guide for the increasing number of business developers and public agents who engage in IS facilitation – and for those companies in need of facilitation.

To address this need, we aim to answer the following question in this study: *Which actions and skills characterize the IS facilitator role?* We follow an in-vivo approach of theory-building (Andersen and Kragh, 2010) and use principles of thematic analysis (Castleberry and Nolen, 2018) on literature and empirical data from Nordic countries to create, refine, and test an action-skill framework describing the IS facilitator role.

First, we introduce the analytical framework applied in the study and uncover the IS facilitator role as described in contemporary scholarly discourse (section 2). After laying out our methodology (section 3), we present the empirical framework developed based on an analysis of a Danish IS facilitation team (section 4.1) and test the integration of the theoretical and empirical framework by setting it into context of experiences from other Nordic IS facilitators (section 4.2). Finally, we discuss the implications of the results for the research field and practice (section 5), conclude, and present avenues for future research (section 6).

2. The industrial symbiosis facilitator role

2.1. Conceptualizing an organizational role: Analytical framework

Roles, which we may define as the “*position or purpose that someone has in a situation, organization, society, or relationship*” (Cambridge Dictionary, 2022), are conventionally studied by role theory. Role theory covers several streams, such as functional, structural, symbolic interactionist, and cognitive role theory. These views differ in their view on how roles are assigned or constructed, how roles are perceived as stable or constantly shaped by context or negotiation, and in their levels of analysis, i.e. the individual or the social context (Baker and Faulkner, 1991; Biddle, 2013). In the present paper, where we study the dynamics of facilitation as the facilitation role characterized by a multitude of actions and skills in an emerging organizational context, we adopt the view that roles exercised as parts of a transition may be defined as “*a set of recognizable activities and attitudes used by an actor to address recurring situations*” (Wittmayer et al., 2017).

As pictured in Fig. 1, we suggest that the facilitation role behavior is composed of actions with different levels of detail, which can be grouped into overarching facilitation *tasks* and subordinate *activities* at different levels. Tasks are performed through activities, which have a descriptive and explanatory function. Activities are enabled by the *skills* activated.

Engaging in activities builds on the entity’s skills, which we define as the capabilities and competences made use of, both at an individual and organizational level (Wernerfelt, 1984; Liska, 1984; Hale et al., 2002). Competences in this context can be understood as value-adding combinations of capabilities and other types of resources (Gorman and Thomas, 1997), where organizational-level competences are embedded in individual-level competences (Cardy and Selvarajan, 2006). Routines and processes combine individual competencies with complementary assets to enable organizational-level capabilities (Dosi and Teece, 1998; Zoioopoulos et al., 2008) and together with sequencing of problems and

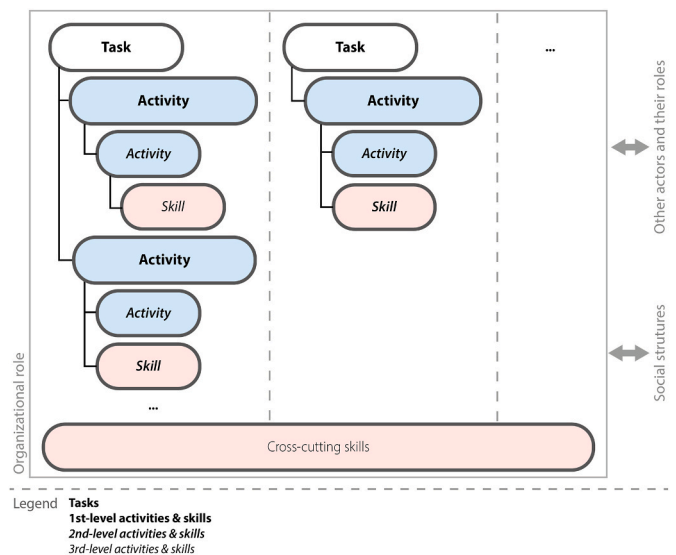


Fig. 1. Action-skill analytical framework defining organizational role. Own illustration based on Fishbein and Ajzen (2010), Hale et al. (2002), Terry et al. (1993), Wernerfelt (1984), and Wittmayer et al. (2017).

group solving, they integrate dispersed knowledge, information, and ideas into collective action (Grant, 1996).

Besides skills, individual attitudes and subjective norms influence role behavior (Fishbein and Ajzen, 2010). External to the entity (visualized in Fig. 1 by the arrows pointing outside the box), the social context in which activities take place is of importance, too. Activities are influenced by interpersonal and social relations as well as the broader social structures (Terry et al., 1993) and other entities and their roles. Wittmayer et al. (2017) refers to the latter as *role constellation*; the web of interacting, interrelating, and co-evolving roles.

We use the presented interpretation of an organizational role to systemically investigate the IS facilitator, its actions, and related skills, in literature and in our empirical data. By using role theory at an organizational meso-level, instead of an individual micro-level, we stress that facilitation of IS requires actions and skills that different organizations can take charge of and address Wittmayer and colleagues’ call (2017) for an investigation of roles in sustainability transitions.

2.2. Unfolding the facilitator role: State of the art

At the organizational level, IS facilitation is often described in terms of embedded individual roles such as “change agent” (Baas, 2011), “champion” (Park et al., 2016) or “shared contact” (Velenturf, 2016), but most often the facilitator is described as a collective role, reflecting that IS mostly occurs in an interorganizational setting. The literature presents a variety of actors being facilitators (Cervo et al., 2019), e.g. private firms (Krones, 2017), ports (Baas, 2008), or public actors such as municipalities (Boons et al., 2017; Spekkink, 2015; Martin and Harris, 2018). The organizational form of facilitation can take the shape of formal structures (Valentine, 2016) such as private-public partnerships or joint ventures acting as formal governance (Velenturf, 2016; Uusi-kartano et al., 2022). The facilitator entity can also occur as a “project group” (Spekkink, 2015) or initiative coordinator (Park et al., 2018). Common to these forms is that they act as a structure for relations and networking (Farel et al., 2016; Park et al., 2016; Sharib and Halog, 2017; Wang et al., 2017), and as a network orchestrator (Paquin and Howard-Grenville, 2013).

The facilitators contribute to the development of IS, which evolves through stages and may even grow into complete industrial systems (Mallawaarachchi et al., 2020) embedded in its surrounding context (Chertow and Ehrenfeld, 2012) and existing IS networks (Schlüter et al.,

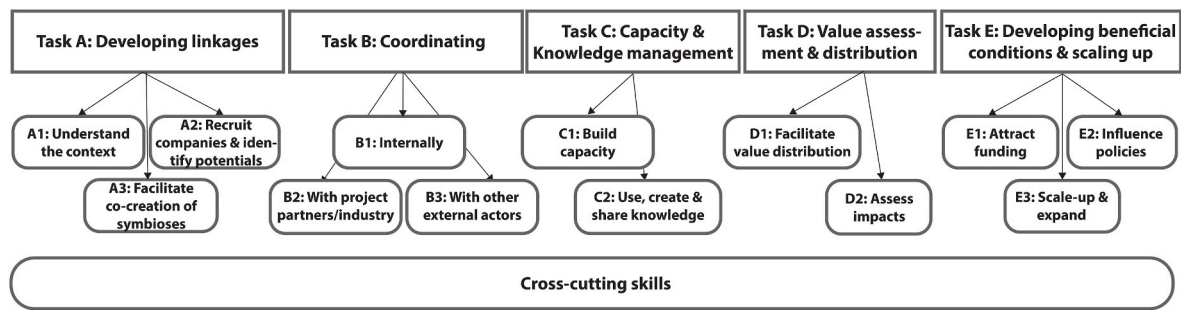


Fig. 2. IS facilitator tasks and 1st-level activities of the action-skill framework developed from literature.

2019). Chertow and Ehrenfeld (2012) presents a three-stage model, where resource exchanges “sprout” and develop into a network or system of interlinked flows, which eventually becomes institutionalized. Similarly, Doménech and Davies (2011), inspired by Powell (1990), describe a continuum of IS development from loose and impersonal bilateral setups to embedded IS networks. The essence of these models is that IS evolves into maturity, e.g. from the existence of the “good idea” to a resilient partnership (Sommer, 2020), and that increasing commitment among the actors of IS benefits and potentials is necessary for the process to emerge. Here, the facilitator plays a key role in creating awareness and interest, matching symbiotic partners, collecting good examples, mapping local resources, screening firms, and establish a collaborative culture (Mortensen and Kørnøv, 2019; Skjødt, 2021). Facilitation is not only important to the creation of new IS networks, but also the expansion of existing ones (Patala et al., 2020).

While research on emergence and facilitation of IS is plenty, a holistic description of facilitator actions, let alone skills, is missing. Therefore, a systematic literature review (Snyder, 2019) was conducted, taking departure in a Web of Science search with the search string (“orchestrat*” or “facilitat*”) and “industrial symbiosis”, covering articles in English language. From the resulting 124 articles, those were selected that 1) view the facilitator as an (inter-)organizational phenomenon, 2) present insights on actions and skills of a facilitating entity, and 3) are based on an analysis of empirical data, leaving a remainder of 20 articles. While reviewing articles for these criteria, it was checked if they refer to other potentially relevant sources. Through this backward snowballing, 7 additional articles were identified. From the final list of 27 articles (see appendix A), 156 quotes referring to actions and skills of the IS facilitator were extracted. An inductive grouping and analysis of these quotes pointed at five main tasks (A-E) including 14 1st-level activities (see figure 2), which are described in the following. The following elaboration is based on the entire mapping of actions and skills (see Schlüter, 2022).

2.2.1. Task A: Developing linkages

Facilitators conduct a variety of activities to developing linkages between firms. Here, an investigation and **understanding of the context** are paramount. The facilitator is described as taking a strategic view of region’s resources (Paquin and Howard-Grenville, 2012) and to review and document their flows (van Beers et al., 2007). Beyond that, the facilitator is reading the political landscape (Hewes and Lyons, 2008) and scanning industrial clusters in an analysis of legal, economic, spatial, technical, and social (LESTS) factors (Cervo et al., 2019). **Identifying potentials for IS and recruiting companies** is a task richly described in IS literature. To do so, facilitators need to have the entire overview and knowledge of the firms (Madsen et al., 2015), use their ability to bring people together, and ‘motivate them to become personally involved’ (Hewes and Lyons, 2008, p. 1339), so that they develop ‘relationships and expertise on specific types of exchanges (Paquin and Howard-Grenville, 2012, p. 89). Facilitators identify

stakeholders based on general symbiosis ideas (Cervo et al., 2019) or find potential users for previously discovered excess resources (Fortuna and Diyamandoglu, 2015; Krones, 2017). In contrast to a more open invitation to join symbiosis developments, the facilitator can engage by developing and presenting already viable solution to firms (Paquin and Howard-Grenville, 2012; Mainar-Toledo et al., 2022). The facilitator uses pre-existing contacts to engage firms (Paquin and Howard-Grenville, 2012), as previously developed relationships and expertise about certain types of exchanges help replicating these (ibid.). Facilitators provide incentives (Yu et al., 2014), judge symbiosis readiness of companies (Paquin and Howard-Grenville, 2012), and aim for potentials with high impact (ibid.; Zucchella and Previtali, 2019). Both building personal relations and a more structured or stylized approach is described in literature (Hewes and Lyons, 2008; King et al., 2020). The facilitator encourages firms to take ownership for starting symbiosis development (Hewes and Lyons, 2008; Lindfors et al., 2020). To **facilitate co-creation of symbioses**, the facilitator creates a general, open interaction space for firms, and adopts ‘formal structures to provide opportunities for interaction’ (Valentine, 2016, p. 69) e.g. through business networks (King et al., 2020), networking sessions (Kokoulina et al., 2018), and workshops aimed at building relations, finding common interests (Lindfors et al., 2020), and incubating innovative ideas (Spekkink, 2015). The facilitator also supports more targeted contact and dialogue between potential symbiosis partners, e.g. through workshops and networking activities (Kokoulina et al., 2018; Paquin and Howard-Grenville, 2012; Patala et al., 2020, p. 5). The facilitator has knowledge to help pair companies (Madsen et al., 2015) and “expertise to coordinate business-networking” (Wang et al., 2017, p. 1577). After prioritizing opportunities and getting a grasp of their implementation potential (Cervo et al., 2019), the facilitator provides more tailored support, e.g. ‘by conducting feasibility studies and/or pilot tests for new processing technologies’ (Park et al., 2019, p. 205) and supports preparations around infrastructure and contracts (Spekkink, 2013). To succeed, facilitators need to be ‘charismatic, active and enthusiastic individuals’ (Kokoulina et al., 2018, p. 534), who have an overview of the process and keep an eye on the final aim.

2.2.2. Task B: Coordinating

The facilitator role is generally characterized by a large amount of coordinating work of all parties and activities within the IS network (Sharib and Halog, 2017; Taddeo et al., 2012; Panyathanakun et al., 2013). **Internal coordination** involves project management, as the facilitator acts as ‘a local project execution hub’ (Park et al., 2019, p. 198). The facilitator is selective in their allocation of time and resources (Paquin and Howard-Grenville, 2013; Park et al., 2019; King et al., 2020). To coordinate with and meet expectations of **industry**, the facilitator conducts surveys (Mainar-Toledo et al., 2022), organizes events and meetings to connect with executives from firms (Valentine, 2016) and other workshops and informative sessions (Lenhart et al., 2015). Many activities here relate to coordinating information sharing

and tackling (potential) confidentiality issues. The communication and timely information sharing is coordinated for **other stakeholders**, too, including technical experts, universities, and governments (Park et al., 2019). The facilitator connects with local community as well (Lenhart et al., 2015; Sharib and Halog, 2017) and builds trust between diverse actors (Paquin and Howard-Grenville, 2012; Baas, 2011; Patala et al., 2020).

2.2.3. Task C: Capacity and knowledge management

IS facilitators encourage knowledge co-creation (including the creation and strengthening of common understandings), change perceptions, and educate and provide training and information to build capacity and manage the complex knowledge. The facilitator is expected to expand their own skills and knowledge continuously and to improve 'the situation of incomplete information' (Yu et al., 2014, p. 471). This includes diverse activities such as linking up with experts (Park et al., 2016), carrying out research (Velenturf, 2016), e.g. by coordinating impact studies (Van Beers et al., 2007), and tailoring activities targeting the attitudes and knowledge of stakeholders and the public (Sharib and Halog, 2017; Velenturf, 2016; Paquin and Howard-Grenville, 2013). The facilitator **uses, creates, and shares knowledge**. They make use of existing knowledge, collect relevant information and knowledge, share knowledge and raise awareness, e.g. through seminar or websites (Yu et al., 2014; Patala et al., 2020). In the same time, the facilitators must remain trustworthy regarding revealing and exploiting the information and knowledge (Madsen et al., 2015, p. 860).

2.2.4. Task D: Assessment and distribution of values

Literature shows that the facilitator secures the assessment and distribution of values. To facilitate fair **value distribution**, they intervene and manage the negotiation process among participating companies (Behera et al., 2012; Park et al., 2019) and make sure fair project benefits are provided (Park et al., 2016). The facilitator **assesses impacts** on economic, social, regional, and environmental dimensions.

2.2.5. Task E: Developing beneficial conditions and scaling up the network

The facilitator also conducts many strategic activities, for developing beneficial conditions and scaling up the network. The facilitator creates alignment of activities and strategic intents across actors, which involves **influencing local and regional government**, and **provision of funding**. Moreover, the facilitator aims at **scaling up** the network (Park et al., 2019) and does not limit their work by geographical boundaries (Lenhart et al., 2015; Fortuna and Diyamandoglu, 2015; Patala et al., 2020).

Having unfolded the facilitator role and the underlying activities and skills as described in the literature, one obvious observation is worth to mention: While the literature is revealing plenty of actions of an IS facilitator, it is scarce in addressing the needed skills. According to the analytical framework, the activities, which form the role of a facilitator and shape the result (i.e. IS development) depend on the facilitator's skills. Understanding these is important as this could help facilitators to build their own capacity, design better facilitation processes and achieve stronger IS networks. This study sheds light on the complexity of the facilitator's actions-skill constellation to address this gap in the literature.

3. Methodology

We relied on an in-vivo approach theory-building in our study, aimed at "systematically discovering an order, here in the shape of a theoretical framework, that fits surprising empirical facts" (Andersen and Kragh, 2010, p. 52), making use of several phases to continuously refining and adjusting a pre-existing framework.

The review of literature provided an initial picture of the IS facilitator role and thereby presented a basis of comparison and foundation for advancing knowledge (Webster and Watson, 2002) for the study that

followed. This study was conducted in three phases, cf. Fig. 3.

An exemplary, empirical action-skill framework was built based on the analysis of the work of a Danish facilitation team (phase 1). With the purpose of making "sense of theoretical ideas by linking them to empirical evidence and at the same time, transforming empirical evidence to results through the use of theory and ideas" (Andersen and Kragh, 2010, p. 52), we compared the resulting framework with the one from literature. Many similarities became apparent, and the empirical framework could be integrated into the structure of the theoretical one, enriching it with new knowledge and details (phase 2). This holistic framework of the facilitator role was tested by collecting and analyzing experiences with IS facilitation from seven other Nordic facilitators (phase 3), evaluating the applicability of the framework in other facilitation contexts.

3.1. Phase 1

The facilitator role was investigated through an in-depth, semi-structured interview with the facilitator team of a project in Aalborg, Denmark (Kørnøv et al., 2020), described in Table 1 and referred to as the Danish facilitation team. As the facilitator in the case was a collective unit, i.e. a team where the members had different facilitation tasks throughout the facilitation process, a group interview rather than individual interviews was preferred as a means to uncover the responsibilities and skills of the facilitator. Here, the group opinion was considered as important as the opinion of the individual (Gibbs, 2012).

The group interview was conducted in two steps. First, the interviewees were asked to map the companies involved in the project and draw links that reflected the exchange of materials, energy, or liquid flows among the companies. Second, the interviewees were asked to describe the process and facilitative approach applied in each case. This was done with respect to (1) their own actions, (2) actions of other actors, (3) technical and professional skills and capacities, and (4) personal skills and capacities.

As in the building of the theoretical framework, our approach for analyzing the empirical data leaned on thematic analysis principles (Castleberry and Nolen, 2018). First, a transcript and translation of the session was made. Afterwards, the data was disassembled: all statements on facilitator actions and skills were reformulated into abstract forms suitable for coding. The extracted 274 statements were given a label, such as 'a23' or 's56', the letter indicating whether it was coded as an action or a skill, the number indicating the location in the transcript. Actions and skills were sorted and mapped in a bottom-up approach, starting with the most detailed description and sorting these under more overarching formulations. One characteristic of this method was that lower-level codes were not removed from the context they were made in. For example, the statement 'to distribute project leaflets (a6)' remained connected to the activity 'to organize project kick-off events (a2)'.

3.2. Phase 2

In this phase, 2nd and other lower-level activities of the two action-skill frameworks were compared and the empirical framework was integrated into the theoretical framework.

3.3. Phase 3

The collection of experiences from other contexts took place as a series of interviews, cf. Table 2, with seven executive facilitators in Nordic countries (Iceland, Norway, Sweden, and Denmark). A selection criterion for the interviewees was that they should be involved in IS networks that are, to some extent, embedded, in the sense that an institutional actor took charge of expanding the network of IS connections. The interviewees had in common that they were all in managing positions of organizations involved in IS facilitation, such as cluster organizations, local municipalities, universities, networks, or NGOs. These differences allowed investigating whether the developed

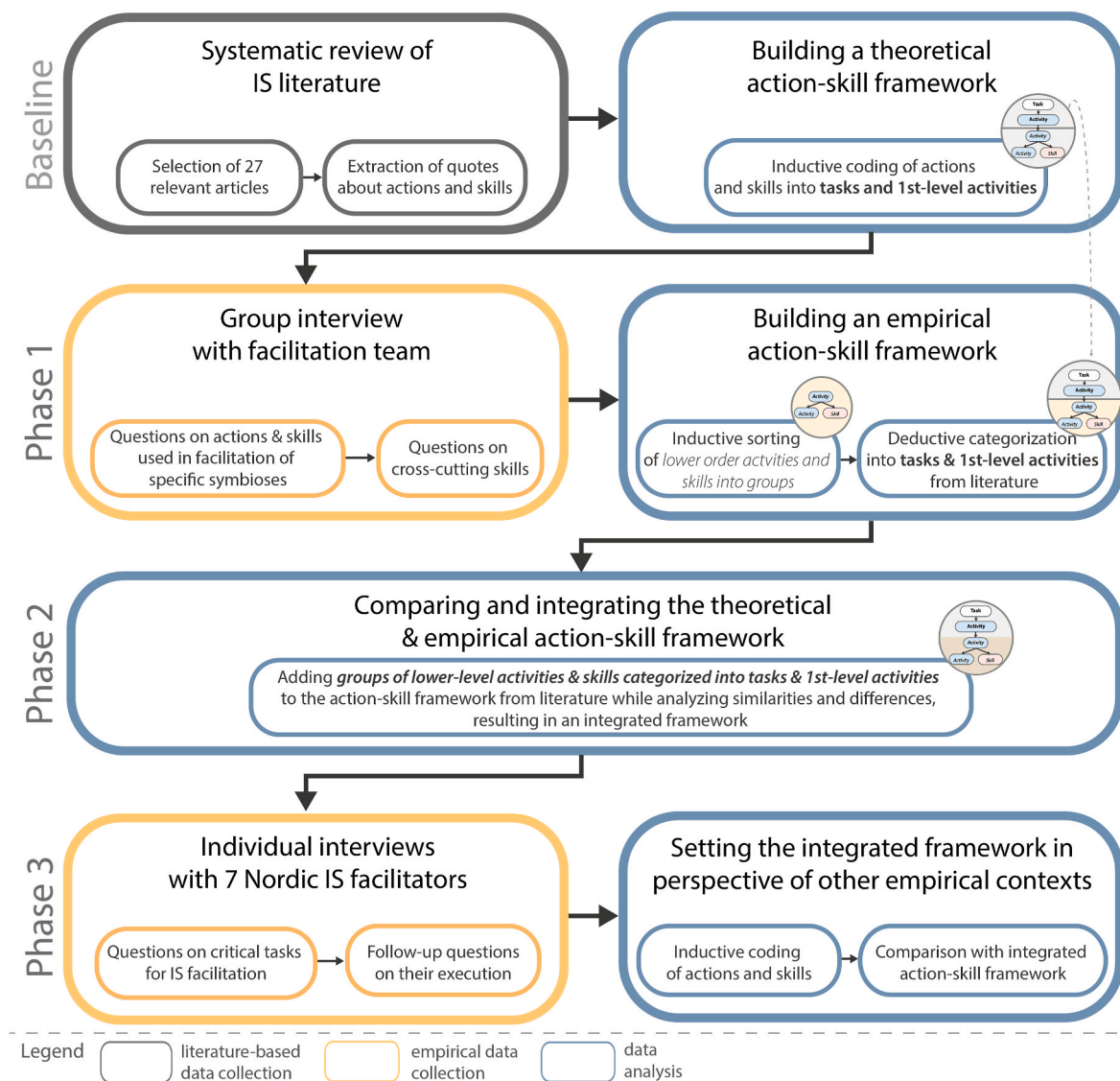


Fig. 3. Work process.

Table 1

Group interview with the Danish IS facilitation project team.

Interviewees' positions	Organization	Country	Date of interview	Form
IS facilitators: One professor, two associate professors, three research assistants	Aalborg University	Denmark	06-03-2019	Oral, 2 h

framework is applicable to different institutional facilitators and geographical contexts. The interviews were conducted on Teams and had a duration of approximately 1 hour each.

Interviewees were asked to identify critical factors for IS development (such as e.g. 'communication', 'funding' or 'knowledge sharing') and describe how they as facilitators support these. By posing this question, all interviewees naturally engaged in an elaboration on which actions and skills they consider important.

The interviews were transcribed, translated, and imported into Nvivo, where all text pieces referring to actions or skills of the facilitator were coded. In an iterative and inductive process, the nodes were merged into higher level categories. The final categories were compared

Table 2

Overview of individual interviews with Nordic IS facilitators.

Interviewee's position	Organization	Country	Date of interview	Form
Senior Symbiosis developer	Kalundborg Symbiosis	Denmark	05-11-2020	Oral
Cluster founder and chairman	Iceland Ocean Cluster	Iceland	10-11-2020	Oral
International affairs and EU-Advisor	Eyde Cluster	Norway	19-11-2020	Oral
Project manager	Paper Province Cluster	Sweden	17-11-2020	Oral
Developer at the Centre of Symbiosis	Municipality of Sotenäs	Sweden	17-11-2020	Written
Climate Strategist & Project Manager	Municipality of Malmö	Sweden	18-11-2020	Oral
Project manager	Energy town Skive	Denmark	19-11-2020	Oral

with the integrated action-skill framework.

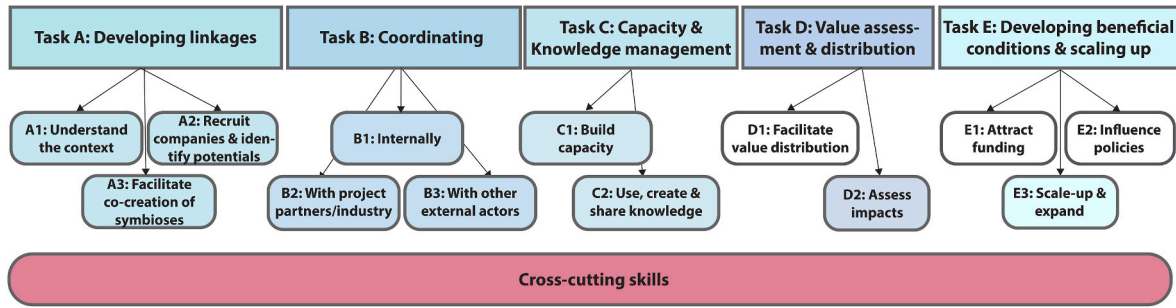


Fig. 4. Tasks and 1st-level activities from literature mapping with those highlighted in color that were identified in the empirical case.

4. Uncovering the IS facilitator actions and skills: results

In the following, the findings are presented and discussed: First from phase 2, i.e., the integration of data from the in-depth interviews with the findings from literature, to describe the integrated action-skill-framework (section 4.1). Second, the findings from phase 3 are elaborated, which describe the results from the integrated framework’s application on other Nordic cases to test its viability (section 4.2).

4.1. The integrated action-skill framework

The group interview with the Danish facilitation team enabled the identification of activities and skills relating to most tasks and 1st-level activities as pictured in the literature (Fig. 2). Thus, Fig. 4 visualizes the mapping of actions and skills of an exemplary, empirical facilitator.

Fig. 5 visualizes these findings in more detail by giving an overview of the 1st and 2nd level activities related to each task. As in the analytical framework, activities are shown in blue boxes, with each task having their own shade, while skills are shown in red boxes. Some of

these actions include even richer descriptions of lower-level activities and skills, but, for a better overview, activities and skills below the 2nd-level are excluded from the following illustration. These details are, however, considered in the following analysis and available upon request.

4.1.1. Task A: Developing linkages

In terms of **understanding the context** (A1), the mapping of local resource flows, was taking place in our case just as in literature, but generally received little attention in the work process. The analysis of LESTS factors and political factors, that is mentioned in literature, was not explicitly mentioned in our group interviews.

Regarding **recruiting companies and identifying potentials** (A2), our case revealed a strong project-based context, in which reaching out to companies through e.g. cold-canvas calling was especially important, and building a new network “from scratch” was central to the facilitators’ work. A number of channels for recruitment seemed important, such as kick-off events, use of media, follow-up on previous contacts, and mobilizing the local business networks. A distinction was made

Task A			Task B			Task C		Task D	Task E	
A1: Understand the context	A2: Recruit companies & identify potentials	A3: Facilitate co-creation of symbioses	B1: Internally	B2: With project partners/industry	B3: With other external actors	C1: Build capacity	C2: Use, create & share knowledge	D2: Assess impacts	E3: Scale up & expand	
Mapping local resource flows	to organize project kick-off events (a2)	to match-make (a21, a229) with possible symbiotic partners	management of internal resources	to make sure data from industry partners is secured and confidential (a133)	to coordinate between partners in and outside the project (a22)	to help companies get a feeling of the systemic effects of changes of their resource use (a219)	Creating and sharing knowledge from experiences in project (a209)	to identify the impacts of a business model	to look beyond the local area (a122)	
	to contact / to reach out (a7, a12, a14, a44, a52); to contact via phone or mail (a1)	to develop and action plan / to develop business ideas (a45), to develop a business idea and model (a64)	to have regular meetings to update each other within the team (a174)	to support, to help (a17, a23, a26)	to take help from other actors (a136)	to bring new ideas and knowledge to companies (a182)	Tell the good stories	to calculate environmental impact (a18) / to “pressure-test” effects on env. (a3, a271)		
	to use the press to get coverage (a223); to use website and newspapers (a224)	to find, compare, and select the best consultants for a specific task (a46, a112, a227)	to put company in touch with students, initiate student project for a specific task (a4, a25, a37)	to maintain interest (a49, a81, a176); to involve, push for action, empower (a97); to motivate (a102)	to be aware of dependency on others (a54)	to facilitate, consult industry (a225)				
	to take the freedom to reject co-operation (a107)		project management (a138) and administration	to insist (and convince people to start/keep working with an idea) (a66); to retain (a246); to convince (a247)	to be in dialogue with authorities (a20)	to be a sparring partner (a24, a42)				
	to find out what to help with (a16)			to maintain contact (a49); to keep contact (a71); to retain potential symbiosis partners (a236)	to be credible (a84, a85)	Legitimize env. agenda in industry				
	to show companies the potentials to work with IS that they have (a220)			to inform/coordinate with other stakeholders in the area, which are also conducting sust. project for industry (a34, a256, a260)						
	to move potentials/companies (that are not fitting into own project) to a project of another stakeholder (a89)									
	to be able to decode the readiness of a firm (s56, s108, s114, s194)									
	to find potential users of waste materials (a103), applications for waste material (a62), and symbiosis partners in general									
Cross-cutting skills										
S1: Social skills			S2: Work approach			S3: Motivation & interest		S4: Ethics & responsibility		S5: Knowledge

Fig. 5. 1st and 2nd-level activities and skills related to task A-E as identified in the empirical case.

between approaching companies with an open possibility to engage in symbiotic collaboration or a targeted invitation to join a specific symbiosis idea.

Even though the “reaching out” filled much in the facilitators’ work, just like identified in the IS literature, a high serendipity of the facilitator work was apparent: Relation to other actors and pre-existing networks of the individual facilitators were made use of.

Moreover, there was a strong focus on assessing readiness of firms. Screening companies and their inputs and outputs, analyzing their value chains, listening to their needs, and making them feel heard were important in the Danish case. Having a strategic approach to identifying and utilizing potentials, including demonstrating potentials to the companies and decode how ready they are for IS, were equally important focus points. Combining insights from literature and group interview, it can be deduced that this readiness is on the one hand related to the likelihood that the firm implements developed symbiosis concepts and that the facilitator’s time and resources lead to results, and on the other hand, related to the motivation and/or ability to take responsibility and ownership for symbiosis development, reducing the workload of the facilitator. Even though the facilitator spends much effort and time on contacting companies and finding potentials, the wish to pass responsibility of symbiosis development onto firms is evident in both literature and interviews.

The identification of potentials was shown to take place through two main strategies: 1) a company-driven identification of potentials, in which the need, inputs and outputs of the firm represent the point of departure for creating concepts and finding symbiotic partners, and 2) idea-driven identification of potentials, where the process takes departure in a symbiotic idea and stakeholders and resources are identified to develop the concept.

Specific to this task was a combination of soft and hard skills. Soft skills include persistence, analytical approach, and an openness to learn, while hard skills include the understanding of recycling technologies, processes, and properties of materials.

In terms of **facilitating the co-creation of symbioses (A3)**, what was called “facilitating dialogue” in literature was called “matchmaking” in our analyzed facilitation team. While literature highlights targeted resource workshops here, the team focused more on personal matchmaking between selected firms.

Furthermore, the analysis revealed a temporal dimension by highlighting the need for ongoing facilitation of this dialogue, reaching beyond an introduction of the firms. Regarding symbiosis implementation, our data showed a strong overlap with activities in literature. The analysis of the group interview showed that the facilitator does not need to provide all activities relevant to e.g., technical aspects of the implementation, by themselves, but can outsource specific tasks to consultants.

4.1.2. Task B: Coordinating

Internal coordination (B1), in form of the management of internal resources, also revealed in our case that facilitators prioritize the time they use on specific companies. Especially, keeping pace, working systematically, and prioritizing among tasks were important. This is in line with literature, where the facilitator is described to become ‘increasingly selective in choosing which exchanges and firms to support’ (Paquin and Howard-Grenville, 2012, p. 89). The analysis of our case revealed that technical skills (in terms of assessing environmental impacts) can help with assessing where to pay attention and how to allocate resources. This is related to the strong impact-drive that the facilitation team showed. Moreover, by connecting students to specific tasks in symbiosis development, the facilitation team showed that facilitators can make use of other roles that their organization inhabits (in this case the one of a provider of higher education) to attach additional resources to symbiosis development. Project management and related actions and skills were just as evident in the empirical case studied as in literature. Working systemically and having regular meetings was

crucial here.

Regarding **coordination with industry (B2)**, our interview reflected the strong focus on personal contact and relations found in literature, and added several levels of detail to it. To maintain interest, involve, and push for action, the facilitator needed to be persistent, able to motivate and create excitement. For building relations with industry, the facilitation team helped with administrative tasks relating to symbiosis projects, which involved firms did not have capacity or time to do. A temporal dimension was added when the facilitators acknowledged the fact that symbiosis development takes time: They addressed this issue by telling ‘the industry partners that they are not forgotten’. Moreover, they highlighted that a systematic approach is needed to keep track of companies for the purpose of not losing the relationship. Here again, being systematic and persistent was considered useful, as many relationships are to be coordinated. Also, in terms of coordination of information exchange, the data reflected aspects of literature, with the difference that in our case this did not include the maintenance of a “database of resources available for IS” (Patala et al., 2020, p. 5). Confidentiality agreements to avoid conflicts regarding data sharing were added as a method to avoid potential confidentiality issues.

For **coordination with and between external stakeholders (B3)**, credibility was a central skill of the facilitator. Moreover, our case showed dependency as a stronger element than literature does. Being aware of dependency on others and to accept help from other actors was a new element. Moreover, one stakeholder group was highlighted to a larger extent: those organizations in the area, which are also conducting sustainability projects with industry. Here, a skill was to open up to other project managers in the region, to be willing to share information. Finding synergies between different projects in the region, making written agreements on how to coordinate with other projects, and setting up a shared database give project managers in the region an overview over which companies have been contacted and are involved in other projects.

4.1.3. Task C: Capacity & knowledge management

In terms of **building capacity (C1)**, and encouraging knowledge co-creation, the facilitation team understood itself as a sparring partner. Even though educating and providing training and information was much more pronounced in literature, bringing new ideas and knowledge to companies, consulting, and helping companies get a feeling of the systemic effects of changes in their use of resources were activities of the facilitation team. The changing of perceptions and common definitions was not explicitly mentioned in the group interviews. **Creating and sharing knowledge (C2)** from experiences in project was strongly related to doing research and developing tools, basing development of these on science. The sharing of knowledge had in contrast to literature a stronger focus on attracting attention to the success stories of the project.

4.1.4. Task D: Value distribution & assessment

While the facilitation team did not engage directly in negotiations between companies (D1), there was a focus on the **assessment of impacts (D2)**. Economic value assessment and business model development are activities that were reflected in our data. Not only to determine elements of the business model and thereby find financial sense in symbiosis, but also the skill to know about business models, to be able to judge whether an environmental improvement makes sense economically was considered relevant.

Less tangible (social) and regional values were not explicitly mentioned, but environmental impact calculation was stressed to a high extent, with the facilitation using ‘many hours’ on this activity. To do so, to be critical and attentive, understanding environmental impacts and trade-offs, and being able to do Life Cycle Analysis and use other tools for impact assessment were needed. Moreover, choosing actual effect calculations over gut feelings was considered crucial. The focus on environmental impact calculation was stressed by the facilitation team

highlighting missing competences or resources on the symbiotic partners' side.

4.1.5. Task E: Establishing a beneficial context for IS network development

The facilitation team did not stress influence on policies and attraction of finances explicitly for establishing a beneficial context for IS network development, indicating that these might be activities of more developed facilitating entities. Just as in literature though, the facilitators did not limit themselves to a local area but rather look beyond it when searching for potential users for a waste resource.

4.1.6. Cross-cutting skills

As the facilitator's skills are scarce in IS literature, a major contribution from the empirical case is the identification of facilitator skills needed to advance IS emergence. While several skills were task-specific, and these are described above, several groups of skills were identified to be relevant and needed while engaged in all tasks. Fig. 6 visualizes the five skills categories and unfold their sub-categories.

A number of skills were mentioned by the facilitation team as generally important. First, the facilitator team pointed to *social skills (S1)*. This skill category refers to the ability to interact and communicate, verbally and non-verbally. Here, having the right attitude and the ability to deal correctly with industry matters. Especially the speaking of different lingos and knowing how to communicate on different levels of abstraction and hierarchy have great significance. While the set of skills presented in S1 was mentioned as the most important, *ethics and responsibility (S4)* appeared as the richest in content. The facilitator should have morally based obligations and duties to others and to larger agreed upon ethical and moral standards and codes. This skill category thus

refers to the facilitator's ability to recognize, interpret and act upon multiple principles and values. Skills range from feeling responsible for the symbiotic linkages created, to involving personal values in facilitation processes and at the same time remaining critical to these and others' values. Remaining neutral and objective in the process, but having values, taking a clear position, being honest, neutral, and vigilant towards ethical problems are crucial.

The skill category referring to *work approach (S2)* represents a collection of behaviors and attitudes applied to tasks and relationships in the workplace, which comprises dimensions such as dealing with problems, detail, change, and time. For the IS facilitator role, this category comprised a systematic, structured, analytic, scientific, and diligent work approach. Beyond that, the facilitation team pointed to the high importance of being insistent, patient, and not giving up as key skills towards symbiotic linkages creation. Furthermore, the *motivation and interest (S3)* of the facilitator is crucial. This category refers to the relation the facilitator has to various ideas, objects, persons, or events in their work, and the thoughts and feelings that underlie their behavior in interaction with these. Remaining truly interested and enthusiastic along the entire process, while facing various challenges was the turning point for the facilitation team. Finally, skills regarding *knowledge (S5)* are of importance, meaning awareness, familiarity, or understanding of objects, situations, science, art, or techniques, gained through experience or study. Here, being knowledgeable about systems thinking were among the most needed skills. Understanding environmental regulations, resource properties, and waste processing technologies was highlighted as needed as well.

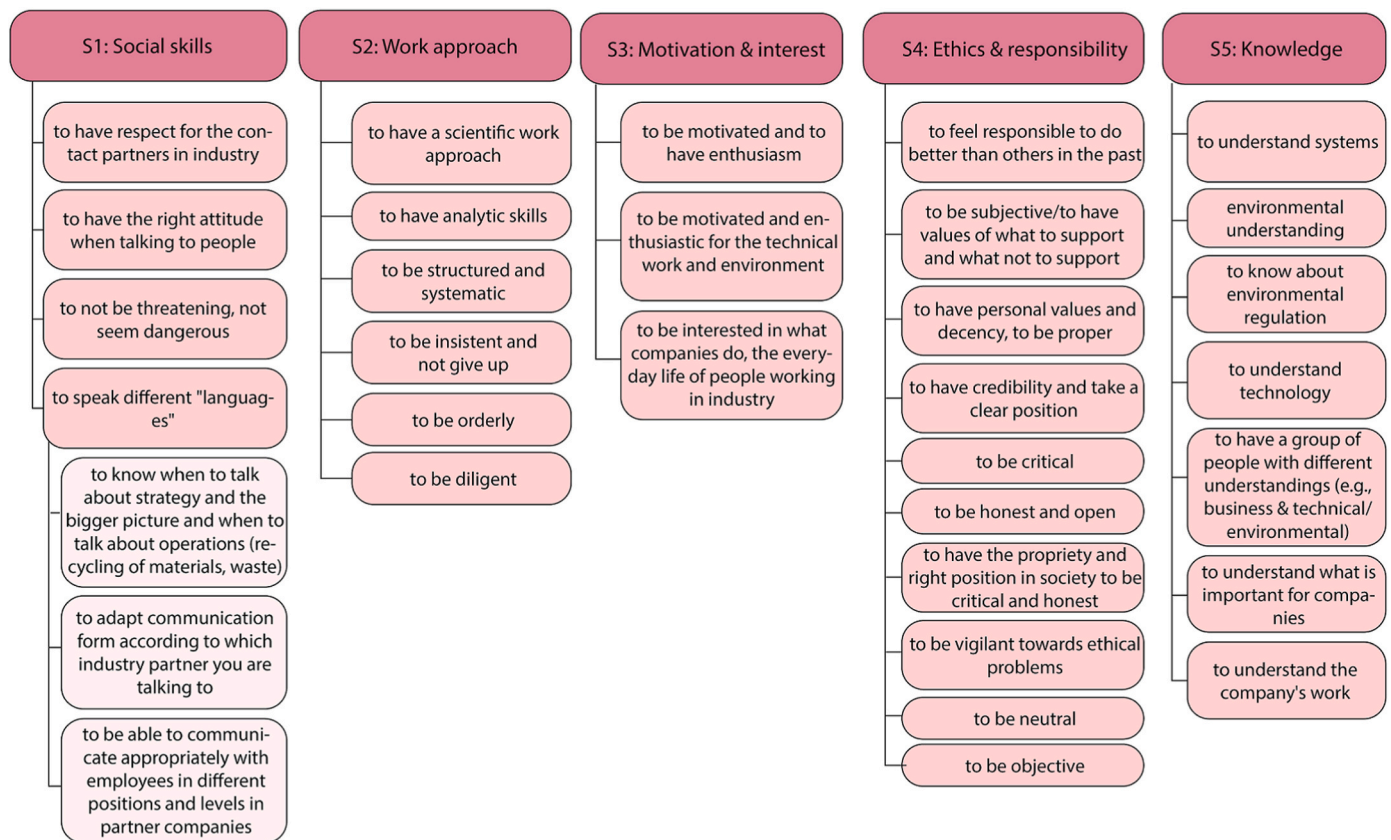


Fig. 6. Categories of skills identified in the empirical case as cutting across tasks.

4.2. Testing the integrated action-skill framework: perceptions of the role

Testing the viability of the integrated action-skill framework on several Nordic cases reveals findings on tasks and skills common for the facilitator role across contexts. Fig. 7 maps tasks and activities, while Fig. 8 visualizes the skills mentioned by the Nordic facilitators.

Mapping the understandings of the IS facilitator activities across the facilitators in the Nordics, cf. Fig. 7, reveals a high degree of overlap with the activities described in the in-depth analysis of section 4.1. All the respondents mentioned the importance of network and being able to bring different stakeholders together. Like in the Danish case, this does not only refer to matchmaking between industry partners, but also to a

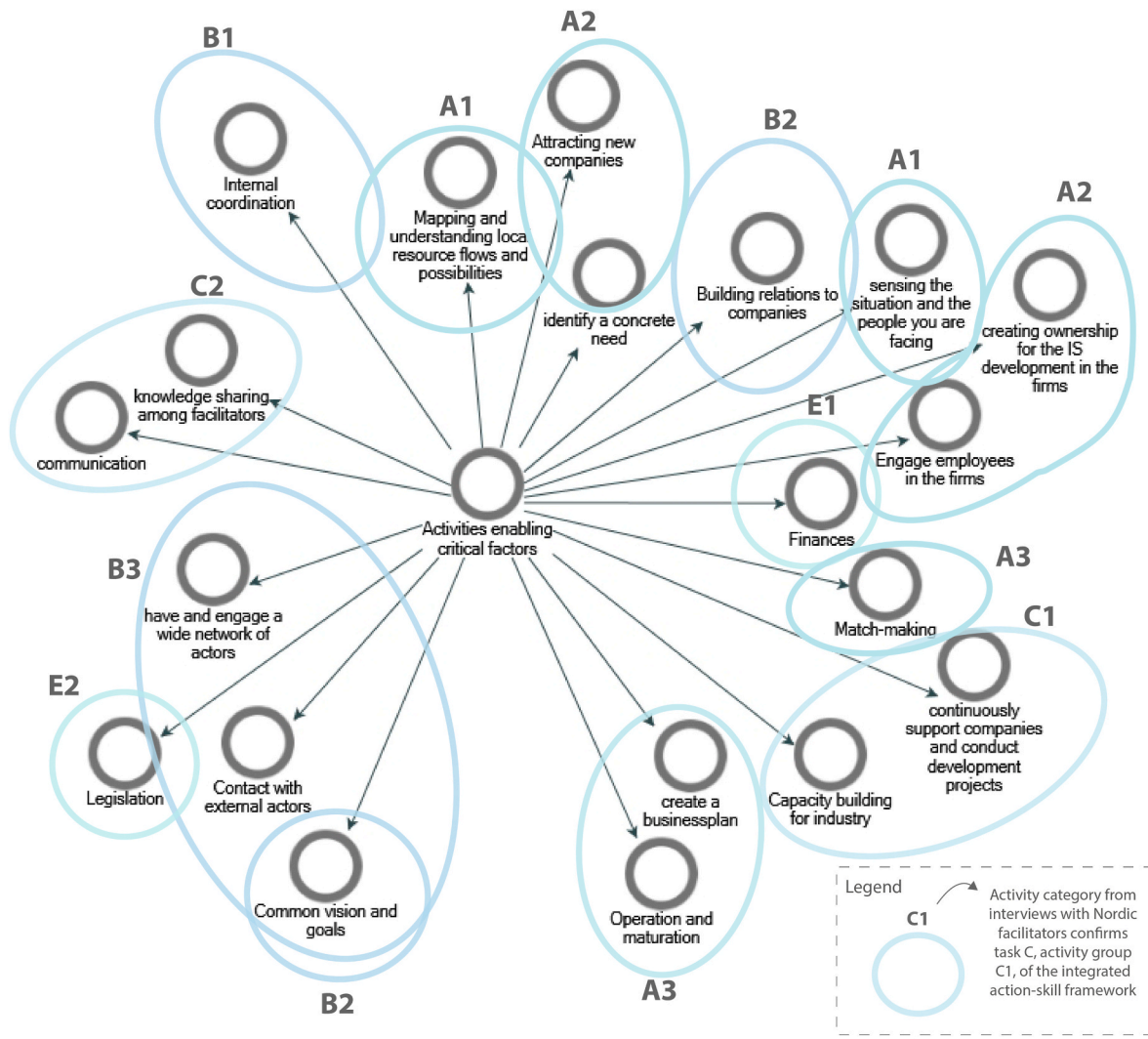


Fig. 7. Activity categories identified through interviews with Nordic facilitators.

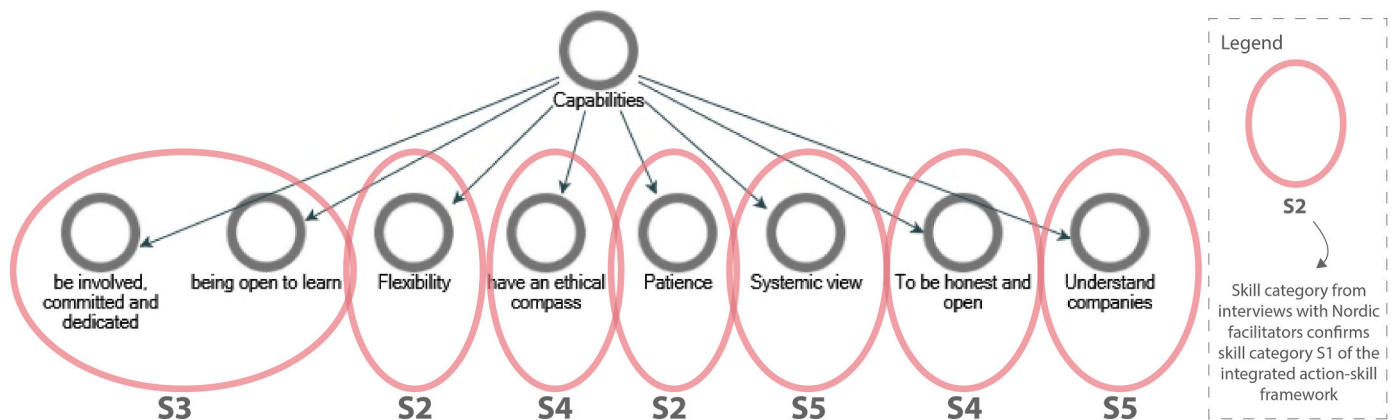


Fig. 8. Skill categories identified through interviews with Nordic facilitators.

wider network of stakeholders and sources of influence, e.g. politicians and policy makers. Judging readiness by understanding the company and its needs and business was similarly important.

The interviews with the facilitators in the Nordic countries revealed eight categories of skills, cf. Fig. 8, which to a large extent are comparable to the results from the analysis in section 4.1. A very strong focus was on the facilitator being open and honest, meaning that expectations are aligned across actors, and that transparency of processes prevails.

In terms of skills, the analysis of the Nordic facilitators revealed that flexibility and patience are important. Another insight is that impact calculation was mentioned to a lower extent by Nordic facilitators, while the Danish facilitator team put a emphasis on technical skills, such as impact assessment. Inspired by Decaux et al. (2020), one can argue that the variate focus is caused by the different background of the facilitators. While the individually interviewed Nordic facilitators were mostly anchored in business and administrative practice, the Danish facilitation team comprised university researchers to whom knowledge and training in life cycle and environmental assessment play a more important role than in other types of facilitating organizations. To incorporate all skills and knowledge bases, there is an agreement among facilitators that there is a need for members with several competences in the facilitation team.

5. Discussion

Our analysis pointed out the activities and skills that IS facilitators experience as the most important when they facilitate IS among companies. The framework developed from literature was investigated and elaborated through an in-depth analysis of the Danish facilitation team and tested by using interview data with seven facilitators across Nordic countries, forming a comprehensive understanding of the activities and skills needed for IS facilitation.

The main topics identified through the interviews with IS facilitators in the Nordics match with what literature in the field has described until now. It is thus presenting a homogenous picture of the action of the IS facilitator role. The social aspect of the IS facilitator role was highlighted, with the interviewees focusing to a large extent on the tasks of networking, relation-building, and connecting of stakeholders. The technical aspects of resource exchanges played a subordinate role in the testing of our framework. Nevertheless, the mapping of local resource flows, which also Van Beers et al. (2007) and Paquin and Howard-Grenville (2012) mention, was reflected. In terms of competences, knowledge on material properties and environmental impacts was considered important on the technical dimension.

The highlighted focus of systems thinking throughout both the group and individual interviews is not reflected in current academic literature. However, practitioner publications, such the material presented by Decaux et al. (2020), stress its importance.

Unanimous is the voice of the IS facilitators regarding social and coordinating skills. To some extent this is already touched upon in academic literature. Our analysis added a new depth to competences relating to these networking-building and coordinating activities, presenting the importance of patience, flexibility, transparency, respect, situational and company understanding, and speaking of different lingos.

The recurring themes in both activities and skills point to the IS facilitator role as part of a process of institutionalization. A homogenization process may be driven by isomorphism, or sustainability ambitions. We see no coercive mechanisms, such as policies and sanctions, that forces the IS facilitator role to comply with some sort of standard or practice. However, there is an element of mimicry, i.e. the copying of successes in face of uncertainty, and adherence to norms embedded in interaction with other professionals and actors from the private and public sectors. To which extent mimicry affects our results is hard to determine, but it must be assumed that mimicry influences the statements leading to intersubjective reasoning.

While several skills were explicitly identified through our study, we can distill implicit skills of the facilitator by looking across the tasks identified in our analysis. This reveals tensions between the tasks that we discuss in the following.

In the work and relation with companies, three examples of activities that are potentially challenging to combine, can be identified. First, the facilitator is expected to *facilitate an honest and open process*, but also has to *respect confidentiality* (1). In literature, Patala et al. (2020) relates to a similar challenge when describing the openness dilemma. The two latter, skill-demanding tensions, relate particularly to the closeness or neutrality to industry. The facilitator must remain *engaged, committed, and dedicated*, but also *neutral using a systems perspective* (2), combining an inside-out perspective with an outside-in perspective and see the firm as part of a larger context based on awareness of resource flows and opportunities across sectors and organizations. Similarly, the facilitator is also expected to *adopt a company's lingo and mindset* but should at the same time *challenge beliefs and push the company towards higher ambitions* (3).

Two tensions relate to the facilitator's way of working and learning within the team. One is that the facilitator needs to *anchor the process locally*, while remaining *engaged globally* (4). While being engaged in a strong local network, the facilitator must be able to understand the ramifications of legislative changes, ideas, and processes at national and international levels. A second tension is to *learn and teach* (5). On the one hand, the facilitator develops capacity in industry, e.g. through organizing training and seminars, and conducting dissemination activities. On the other hand, the facilitators themselves learn through engagement with companies and have to stay updated on technical, regulatory, and social aspects of specific IS developments.

Three last tensions can be highlighted, which relate to conflicting aims and results of facilitation work. We observed that a common activity is that the facilitator *evaluates in how far companies are ready to join IS and makes decisions which companies to work with*, sometimes rejecting firms with too low readiness. However, they are also *responsible for developing capacity and knowledge* (6), an activity that could be considered especially relevant for firms with lower readiness levels. Another tension is that the facilitator has to *provide space for open communication and idea exchange*, but at the same time *must guarantee that this leads to closure and implementation* (7). Last, but not least, the facilitator must support *long-term development while reaching short-term goals* (8). The facilitator is often expected to deliver direct environmental, social, and economic impact, desired and required by funding opportunities on the short run. At the same time, the facilitator must remain aware of network development and capacity building aims, which often is not achievable or measurable in the short term.

By discussing these tensions between tasks, it becomes evident that the facilitator role is skill demanding and very contextual. As the context changes, several determinants and critical factors will influence the IS emergence process (Mortensen and Kørnøv, 2019), and actors involved in the process learn and expand their knowledge and aspirations. IS facilitators may rely on their existing skills but must also expect that skills will become insufficient to keep up with the process of network development.

6. Conclusion and avenues for future research

Exploring the answer to our research question: *which actions and skills characterize the IS facilitator role*, we viewed IS facilitation through the tasks and skills of a facilitation entity. The study shed light on the complexity of being a facilitator, by constructing an analytical action-skill framework, developing it through a systematic review of IS facilitation literature, and then integrating it with empirical insights from Nordic cases. We filled a gap in literature by unfolding the specific activities taken by facilitating entities and uncovering related skills.

The analysis revealed a role in the process of homogenization. Activities of the facilitator, which have been identified across literature

and practice, include among others the recruitment of companies to the network, including a readiness analysis, a use of pre-existing networks, and an element of serendipity. We identified explicitly relevant skills of the facilitator, namely social skills, work approach, motivation and interest, ethics and responsibility, and knowledge.

Following the analysis, we discussed eight specific tensions between identified actions, that make the role of the IS facilitator demanding and context-dependent, thereby implying an additional, implicit skillset of the facilitator.

Three avenues of future research may be pertinent to further exploration of facilitator activities and skills.

First, investigating the relation between individual facilitators' action-skill frameworks and their organizational characteristics (such as form, business model, ownership, size) holds potential. Comparative studies could reveal limitations and opportunities for building and using certain skills and tasks depending on organizational characteristics, but also determine suitable organizational characteristics for different facilitating contexts (such as cultures, network development stages).

Second, a comparison of the IS facilitator role to other roles could provide a clearer picture of the roles that organizations take in the sustainability transition, and the skills required. Skills for different sectors transitioning to sustainability have already been discussed in literature (e.g. see Charatsari and Lioutas, 2018), but as a means to realize a circular economy, investigating the organizational competencies of enabling and orchestrating organizations, such as the IS facilitator, is a needed future research avenue. Not only proving the need for specific skills, but also creating guidelines for their evaluation and development is of high practical importance. Furthermore, viewing and understanding the IS facilitation as a homogenous role may not be the only way to understanding the complexity of action-skills constellation. Facilitator functions, both at the group and at individual level, may reveal important insights. Last, but not least, the network level holds opportunities for crucial insights: How can tasks and skills best be divided among facilitating organizations with different characteristics within an IS network?

Third, as Wittmayer et al. (2017) argue that '*changes in (the shared understanding of) social roles can be indicative of transformative change in the social fabric of society*' (p. 47), the snapshot of what currently characterizes the IS facilitator role can represent a starting point to show potential transformative changes by analyzing how the role changes. Longitudinal studies could follow the evolving of IS facilitator organizations, the development of their actions and skills, but also shed light on potentially changing (self-)perceptions of the IS facilitator role.

Appendix A. Articles used in systematic literature review

Articles used in systematic literature review to build the theoretical action-skill framework.

Article (Author(s) and publication year)	Empirical case	Number of quotes (actions & skills) used in framework
Baas (2011)	Rotterdam Harbour and Industry Complex, the Netherlands; Östergötland region, Sweden	1
Behera et al. (2012)	Ulsan Eco-industrial Park, South Korea	5
Cervo et al. (2019)	Humber region, UK	16
Fahmy et al. (2021)	Kawerau industrial cluster, New Zealand	1
Fortuna and Diyamandoglu (2015)	NYC WasteMatch, USA	7
Hewes and Lyons (2008)	Devens, Massachusetts, USA; Komsomolske and Cherkassey, Ukraine	8
King et al. (2020)	ASPIRE matchmaking marketplace, Australia	8
Kokoulina et al. (2018)	Finnish Industrial Symbiosis System (FISS), Finland	7
Krones (2017)	Casella-Hypertherm Recycling Partnership, Upper Valley, UK.	2
Lenhart et al. (2015)	Rotterdam, the Netherlands	8
Lindfors et al. (2020)	Norrköping, Sweden	3
Madsen et al. (2015)	Two companies in the process of establishing an IS-exchange	3
Mainar-Toledo et al. (2022)	Tannery district of Ponte a Egola, Italy; Ennshafen port & business park, Austria; Chemiepark, Austria; Okamika – Gizaburuaga, Spain; Bildosola – Artea, Spain	4

(continued on next page)

Our study reveals important practical implications for practitioners who engage in creating industrial symbiosis. The facilitation of industrial symbiosis is sensitive to variations in the set of skills and actions that are employed during the process and different skills and actions are conducive at different points of time. In consequence, the demand for a variety of skills and actions calls for facilitation to be organized through a team-oriented set-up with multiple facilitators and interorganizational arrangements. Furthermore, industrial symbiosis must be curated by a proactive approach where industrialists, policy makers, and business services join forces and design a flexible framework that simultaneously sets a direction of development and allows for unfolding processes that cannot be anticipated in advance. Thus, a combination of bottom-up processes and top-down guidance is advantageous and necessary and should take place in an organized setting, in which activities and motives across a multitude of actors can be aligned.

CRedit authorship contribution statement

Leonie Schlüter: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Lucia Mortensen:** Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Writing – review & editing. **Rikke Drustrup:** Conceptualization, Methodology, Validation, Formal analysis, Investigation. **Allan Næs Gjerding:** Conceptualization, Methodology, Validation, Writing – original draft, Writing – review & editing, Supervision. **Lone Kørnøv:** Conceptualization, Methodology, Validation, Supervision. **Ivar Lyhne:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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(continued)

Article (Author(s) and publication year)	Empirical case	Number of quotes (actions & skills) used in framework
Oguntoye et al. (2019)	Gauteng, South Africa	3
Paquin and Howard-Grenville (2012)	National Industrial Symbiosis Programme (NISP), UK	20
Paquin and Howard-Grenville (2013)	National Industrial Symbiosis Programme (NISP), UK	4
Park et al. (2019)	National Eco-Industrial Park Program, South Korea	16
Park et al. (2018)	Sustainable Industrial Network Program, Colombia	1
Park et al. (2016)	National Eco-Industrial Park Development Program, South Korea	4
Patala et al. (2020)	Finnish Industrial Symbiosis System (FISS), Finland	12
Sharib and Halog (2017)	Rubber City, Kedah, Malaysia	2
Spekkink (2013)	Canal Zone, Zeeland, the Netherlands	2
Spekkink (2015)	Sloe Area and Canal Zone, Zeeland, the Netherlands	2
Velenturf (2016)	Humber region, UK	1
Wang et al. (2017)	Industrial symbiosis coordination network, China	5
Yu et al. (2014)	Tianjin, China	9
Zucchella and Previtali (2019)	A “waste is food” restorative ecosystem, Lombardy, Italy	4
27 articles		158 quotes

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