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Virtual hackathon as ICT-enabled boundary arrangement for municipal innovation

Anu Helena Suominen*

Tampere University, P.O. Box 300, Pohjoisranta 11, 28100 Pori, Finland.
E-mail: anu.suominen@tuni.fi

Vilho Jonsson

Curlabs, Kungsholmstorg 10 1 tr., 112 21 Stockholm, Sweden.
E-mail vilho.jonsson@curlabs.com

Johan Bäckman

Curlabs, Kungsholmstorg 10 1 tr., 112 21 Stockholm, Sweden.
E-mail johan.backman@curlabs.com

Jessica Fogelberg

Knivsta kommun, Centralvägen 18, 741 40 Knivsta, Sweden.
E-mail jessica.fogelberg@knivsta.se

Eric Eriksson

Knivsta kommun, Centralvägen 18, 741 40 Knivsta, Sweden.
E-mail eric.eriksson@knivsta.se
* Corresponding author

Abstract: This paper addresses the virtual hackathons as ICT-enabled boundary spanning arrangements (IBSA) and their knowledge integration in the municipal innovation management context. Specifically, it focuses on the boundaries and boundary objects for boundary-bridging in virtual hackathons. Therefore, this paper presents a case study in a Swedish multi-disciplinary municipality carrying out an intra-organizational hackathon in virtual collocation for public sector innovation creation. As a result, the paper reveals the discovered boundaries in five boundary categories: individual, domain-specific, task-oriented, spatial, and temporal. Furthermore, the multiple boundary objects utilized for boundary-bridging in a virtual hackathon are presented. Moreover, the paper illustrates the innovation output of four virtual hackathon teams. Thus, the results clarify the virtual hackathon as IBSAs. The paper contributes to the literature on hackathons as IBSA as well as knowledge integration, particularly in terms of boundary objects in virtual innovation contests in municipal organization context.

Keywords: innovation contest; hackathon; virtual hackathon; boundary; boundary object; boundary bridging; ICT-enabled boundary spanning arrangement; IBSA;

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1 Introduction

Physical distancing demands atypical approaches for innovation activities. Knowledge integration is central to innovation, and boundary-crossing, either spanning or bridging, is focal to knowledge integration (Tell, 2017; Van de Ven, A. H. and Zahra, 2017). Yet in the virtual environment, the cross-learning type of knowledge integration (Enberg, 2012), and the use of traditional boundary objects (Star, 2010; Star and Griesemer, 1989) in internal and external organizational boundary bridging are not a seamless fit. Hackathon, one type of innovation contest, can be carried out in different collocations: radical, virtual – and hybrid (Halvari et al., 2021). Virtual hackathon i.e. is carried out by the means of ICT (e.g. Jussila et al., 2021), is a novel concept. Virtual hackathons are considered ICT-enabled boundary spanning arrangements (IBSAs), which consist of assemblages between rules, processes, and ICT applications (Termeer and Bruinsma, 2016), but are under-researched as IBSAs. Specifically, research on virtual hackathons as IBSAs and the boundary objects utilized in their knowledge integration for innovation outputs is at its early stages, thus the concepts are unclear and not operable for value-creation in practice. Thus, there is a shortage of in-depth studies of virtual hackathons as IBSAs and their effects on boundary-bridging knowledge integration for innovation output in the intra-organizational setting. Therefore, the goal of the study is to clarify the virtual hackathon concept as an IBSA. We focus on the knowledge integration in virtual hackathon and particularly on boundary bridging by investigating the discovered boundaries and boundary objects to bridge them in pre-hackathon and hackathon event phases. The study of boundaries is carried out with the categorization of five knowledge boundaries (Hernes, 2004; Tell, 2017) and the view on boundary objects is wide, from tangible to digital, from concrete to metaphoric (Chang and Kuo, 2021; Haines, 2015; Koskinen, 2005; Marheineke et al., 2016b; Pawlowski and Robey, 2004; Sapsed and Salter, 2004; Star, 2010; Star and Griesemer, 1989; Tell, 2017; Yakura, 2002). Moreover, the results of virtual hackathon knowledge integration, the innovation outputs, are examined. Our main research question is: *"How is boundary bridging knowledge integration for innovation output carried out in a virtual hackathon as ICT-enabled boundary arrangement (IBSA)?"* Our sub-questions for answering the main research question are:

> *"What and of what category are the discovered boundaries in a virtual hackathon?"*
>
> *"What are the boundary objects utilized for boundary bridging in a virtual hackathon?"*
>
> *"What innovation outputs are resulting from the knowledge integration in the virtual hackathon as IBSA?"*

The context of the study is a virtual cross-disciplinary intra-organization setting in a municipal organization.

The article is formulated as follows: First, in the introduction, we give background regarding our research problem and present the research questions, second, we briefly describe the aspects of boundaries, boundary bridging, boundary objects, and ICT-enabled boundary spanning arrangements and virtual hackathons. Third, we portray the methodological choices we have done for our research. Fourth, we illustrate our research results and fifth we present the conclusions and practical implications together with further research suggestions.

2 Virtual hackathons as IBSAs

Knowledge integration, Boundary objects and ICT-enabled boundary spanning arrangements

Knowledge integration, boundary objects, and boundary spanning have been studied in organizational and network settings (e.g. Enberg, 2012; Van de Ven & Zahra, 2017), in innovation context (e.g. Mäenpää et al., 2016), and in virtual collaboration (Marheineke et al., 2016b), and boundary bridging in virtual innovation communities (e.g. Marheineke et al., 2016a). In the literature, the notions of knowledge 'boundary spanning' or 'boundary bridging' are utilized incoherently and interchangeably, yet signifying crossing knowledge boundaries (see e.g. Marheineke et al., 2016a; Termeer and Bruinsma, 2016). As the term 'boundary spanner' often refers to humans (Van de Ven, A. H. and Zahra, 2017), in our study we prefer the term boundary bridging as the study does not focus on people, but on objects and processes that are present in virtual hackathons. Knowledge integration refers to *"the coordination and recombination of knowledge from different individuals, disciplines, and functions"* and the integration of knowledge across boundaries denotes it occurring ***"****between individuals within departments, between departments and firms, between firms, and between communities and countries."* (Tell, 2017. p. 1) The intentionality of the combination for a specific task achievement is emphasized in knowledge integration definitions (Berggren et al., 2011; Tell, 2017), which across boundaries entails both stocks and flows of knowledge and purposeful activities of organizational actors (Tell, 2017). Knowledge integration is required in new knowledge creation, advanced products and systems development, and advanced social services delivery (Tell, 2017) Therefore, knowledge integration across boundaries is fundamental to innovation (Tell, 2017; Van de Ven, A. H. and Zahra, 2017). Along the three stages of knowledge integration, i.e. knowledge identification, knowledge acquisition, and knowledge utilization, knowledge coordination, is an important intermediate process in a multi-stakeholder environment presupposing collaboration (Tiwari, 2015). In the literature, knowledge integration is approached by either relying on structural mechanisms or enabling cross-learning that emphasizes frequent communication and extensive mechanisms based on knowledge sharing (Enberg, 2012).

In organizations, knowledge boundaries are caused by the increasingly specialized, differentiated and widely distributed knowledge (Tell, 2017). Different types of boundaries have been detected, such as semantic, syntactic, and pragmatic boundaries (Carlile, 2002). Furthermore, Tell (2017) proposes five categories of knowledge boundaries: 1) individual boundaries, 2) domain-specific boundaries, 3) task-oriented boundaries, 4) spatial boundaries, and 5) temporal boundaries. To some extent similarly (Hernes, 2004) has presented cognitive, social and physical boundaries. The combination of Tell's and Hernes' boundary categorizations is presented in Table 1.

Table 1 Five boundary categories and boundary explanations

Boundary category	*Boundary explanation*
1. Individual	
1.1. Specialized individuals with skills and expertise	The boundaries included in the knowledge integration of experts are magnified by the increased specialization of individual knowledge. (Tell, 2017)
Cognitive boundaries (Hernes, 2004)	Relate to the ways differences in meanings, knowledge, and language complicate or suppress collaboration. People construct shared meanings about the situation, yet by focusing on particular situational aspects or centring certain elements, the frame of the issue may diverge, e.g. intellectual and methodological boundaries.
1.2. Social category (Tell, 2017)	Due to cognition as individual ability, i.e. competence, since different role orientations result in social networks for individuals
Social boundaries (Hernes, 2004)	Are difficulties in social capital building, since norms of reciprocity and trust are the foundation of connections among people. Identifying oneself to 'us' and 'them' reflects the social boundaries, potentially causing distrust and exclusion, whereas strong social capital enables bridging communities.
2. Domain-Specific (Tell, 2017)	Knowledge is also a social phenomenon involving the drawing of boundaries among the interactions between individuals and groups. Scientific disciplines and subdisciplines, communal practices e.g. crafts, guilds, and professions are regarded as social communities. Domain-specific knowledge is the 'knowing-what' of many knowledge-based communities, which define the knowledge domain and knowledge boundaries in specific knowledge bases, for example, scientific disciplines, technological and engineering areas, professions, communities, common interests, etc.
3. Task-Oriented (Tell, 2017)	The task refers to the assigned piece of work, as in a problem waiting to be solved. Task-oriented procedural knowledge refers to 'knowing-how'. Procedural knowledge involves task organization and task execution capabilities.
4. Spatial (Tell, 2017)	Dispersion across the world to different physical and cultural environments, cause varying knowledge focus across geographical locations. Yet, all important elements in the development of knowledge emerge in the local context. Knowledge boundaries emerge with different sites and call for an examination of the types of proximity that lead to diffusion across space.
Physical boundary (Hernes, 2004)	Physical boundary involves technological or spatial barriers that reduce the chance of encounters between actors or hinder the intensity of interactions.
5. Temporal (Tell, 2017)	The sequencing of events in time creates boundaries between 'slots' in time. Knowledge is context-specific in relation to time. Temporal boundaries also emerge in another context, such as history-dependent knowledge from the past. Knowledge has one linear time conception: past, present and future tenses. Time is not necessarily continuous; it can be occasional, intermittent, sequenced, parallel, and/or paced. This breaking down of time can help to focus effort and learning but creates knowledge boundaries and problems related to the synchronization of time.

Tell (2017) has presented fifteen mechanisms for bridging the five categories of boundaries. *Objects* can serve as a boundary-bridging mechanism for especially knowledge acquisition, one of the stages of knowledge integration. Furthermore, a variety of boundary objects or mechanisms has been studied that can be used for integrating knowledge across boundaries (Van de Ven, A. H. & Zahra, 2017). Boundary objects can be concrete or abstract (Star, 2010; Star and Griesemer, 1989), or metaphoric (Koskinen, 2005) "bridges". Their boundary bridging mechanism is founded on the attractiveness of tacit and codified elements of artefacts (Tell, 2017). Concrete or abstract boundary objects are e.g. maps, repositories, standardized forms, prototypes, drawings, etc. that allow contributing to a more comprehensive objective between groups with different perspectives and aims (Star, 2010; Star and Griesemer, 1989). Metaphoric boundary objects contribute to tacit knowledge sharing and understanding between people (Koskinen, 2005). Boundary objects may be *"weakly structured in common use, and become strongly structured in individual-site use"* (Star and Griesemer, 1989, p. 393), which can be interpreted that they are *"plastic enough to adapt to constraints, but robust enough to have a common identity"* (Haines, 2015, p. 1). Objects can facilitate expressing an idea or product, without formal theoretical presumption (Tell, 2017), since *"They have different meanings to different parties, yet their structure is identifiable to multiple worlds, making them a means of translation."* (Haines, 2015, p. 1) Different boundary objects bridge boundaries in different categories, e.g. prototypes and drawings bridge domain-specific knowledge boundaries such as those between occupational communities or task-oriented boundaries, and Gantt charts and other visualization methods using timelines enable the bridging of temporal boundaries e.g. (Tell, 2017; Yakura, 2002), and besides Gantt charts, other project management tools, such as PERT, cost–benefit analysis, earned value analysis, critical path method (CPM) and work breakdown structures are considered boundary objects, too (Sapsed and Salter, 2004). Even a pitch can serve as a boundary object that facilitates e.g. collaborative design of the technology as a product (Haines, 2015). Moreover, as boundary objects are considered shared information systems (Pawlowski and Robey, 2004), a variety of tools for virtual collaboration such as web-based groupware (Marheineke et al., 2016b) and as technology evolves, currently also Learning management systems, an online platform integrating digital tools to facilitate e-learning delivery and the co-construction of knowledge, that can include for example Zoom video conferencing tool (Chang and Kuo, 2021). In their literature research on the importance of boundary objects for virtual collaboration Marheineke et al. (2016b) highlight the competence change while using boundary objects, and boundary workers also mediate the collaboration process. However, even though much empirical research has been shown that boundary objects facilitate bridging boundaries, they can also hamper the bridging (Tell, 2017) or have their limitations (Sapsed and Salter, 2004).

ICT-enabled boundary spanning arrangements (IBSAs) are discovered to help to bridge and cross different organizational boundaries. IBSAs consist of assemblages between rules, processes and ICT applications. Several types of contributions of IBSAs are presented in the governmental context to bridging physical, cognitive and social boundaries (Termeer & Bruinsma, 2016). Virtual hackathons are considered one type of IBSAs (Termeer & Bruinsma, 2016).

Virtual hackathon as IBSA

Hackathon as an innovation management method has spread from its origins in the 1960s within the Information Technology industry to other sectors (Leckart, 2012; Zukin and Papadantonakis, 2017), and as a specific type of innovation contest, it has been studied by some extent (Medina Angarita and Nolte, 2020). Hackathon has been defined as *"A hackathon is one type of organized, goal-driven innovation contest, a short time-bounded event with a challenge to be solved creatively in coopetition and collocation of teams, whose results are presented and recognized in a ceremony at the end of the event."* (Halvari et al., 2020) Before hackathon event there is pre-hackathon, and after the event post-hackathon phases, which are carried out according to the hackathon goals (Pe-Than et al., 2019; Pe-Than and Herbsleb, 2019). The event itself include creation process and celebration process (Halvari et al., 2020). Hackathon as one type of innovation contest, can be carried out in different collocations: radical (Pe-Than et al., 2019; Pe-Than and Herbsleb, 2019; Teasley et al., 2000), virtual (Jussila et al., 2021) and their hybrid (Halvari et al., 2021). Radical collocation signifies situation where the team members are in the same physical space for the duration of the event, and virtual where the integration between the members and teams is usually carried out via information and communication technology (ICT), and hybrid is the simultaneous combination of radical and virtual collocations. Hackathons inflict boundaries in diverse categories for knowledge integration, which are varied in terms of collocation. Thus, virtual hackathons require boundary objects specific for boundary bridging in virtual collocation. Therefore, the cross-learning type of knowledge integration (Enberg, 2012), and the use of traditional boundary objects (Star, 2010; Star and Griesemer, 1989) in internal and external organizational boundary spanning are not a seamless fit in the virtual environment. Virtual hackathons are considered as IBSAs (Termeer & Bruinsma, 2016), which means that they are arrangements that help to cross and bridge knowledge boundaries.

3 Methodology

Virtual hackathon is a novel concept that particularly as IBSA is under-researched. Thus the nature of this research is exploratory (Saunders et al., 2008). As the aim of this study is to clarify the boundary bridging knowledge integration in virtual hackathons, the philosophical program of this study is pragmatism (Morgan, 2014). The research strategy of the study draws from a combination of intensive case study approach and action research approaches (Eriksson and Kovalainen, 2008). The study is carried out in the case organization (e.g. Siggelkow, 2007). The research data collection has been carried out with the participatory action research method with both physical and virtual participation.

The case organization under research is a municipal organization in Sweden with a longitudinal three-year project that aims to develop the organization's innovation culture. The municipality is a multi-disciplinary organization providing versatile services of health and social care, education, leisure time and culture, building and civil engineering etc., At the core of the innovation culture development has been the implementation of hackathon methodology with three events during 2020–2021 with varying collocations: physical, virtual and hybrid. Due to its idiosyncrasy (van Maanen et al., 2007), this article focuses on one intra-organizational virtual hackathon event for employees of multiple

municipal departments in November 2021 with 21 hackers in 4 multi-disciplinary employee teams, in addition to mentors and a jury. The event in virtual collocation included also pre- and post-hackathon phase activities for participants with observed training for digital competence building as well as post-hackathon interviews and mentored team follow-up. In this study, we concentrate on the pre-hackathon and hackathon event phases. The analysis of boundaries is based on the five boundary categories (Hernes, 2004; Tell, 2017) and their boundary explanations. The analysis of hackathon event is according to the hackathon attributes presented in the literature (Halvari et al., 2020). Furthermore, the case study analysis has been descriptive with data and researcher triangulation. The multi-disciplinary researcher group together with the subject matter experts from the public sector will improve the validity of this research.

4 Results

Boundaries of a hackathon in virtual collocation

Hackathon by its definition is *"one type of organized, goal-driven innovation contest, a short time-bounded event with a challenge to be solved creatively in coopetition and collocation of teams, whose results are presented and recognized in a ceremony at the end of the event."* (Halvari et al., 2020), is a purposeful activity of organizational actors for a specific task achievement, i.e. an organized contest aiming at innovation. Thus, to achieve innovation hackathon demands knowledge integration across boundaries i.e. intentional coordination and recombination of knowledge from different individuals, disciplines, and functions. Virtual hackathons carried out in virtual collocation (Jussila et al., 2021) call for the use of information and communication technology (ICT) as a way to connect the individuals and teams participating in the event. By its definition, hackathon, especially virtual hackathon, create boundaries that ought to be bridged for knowledge integration. Virtual hackathon is a short time-bounded event, in virtual collocation, which is organized, it has goals, is a contest with predefined challenge, its process includes team co-opetition, i.e. simultaneous collaboration and competition, the event has two consequent phases of creation and ceremony, which all create various boundaries belonging to different boundary categories. Furthermore, as an organized event it demands preliminary organization of the goals, recruiting participants, predefining the challenge in pre-hackathon phase. Additionally, operating in virtual hackathon demands certain digital competence (Jonsson et al., 2021), which either must be verified or trained. Depending on the event organizing, the preliminary idea pitching and/or team building can take place either before the event be either or at the beginning of the event. Therefore, the pre-hackathon phase also creates boundaries that have to be bridged for hackathon knowledge integration. In the innovation literature, it is often highlighted that the intersection of multi-domain organization and cross-functional teams are fruitful zone for innovation, thus hackathon recruitment pursues participants from versatile backgrounds. Yet, that also creates boundaries to bridge, which can be carried out with the help of appropriate boundary objects. In Table 2, the discovered boundaries of two categories: Individual and Domain-specific and multiple boundary objects utilized for boundary bridging in the pre-hackathon phase are presented according to the activities and their aims. In Table 3 a and Table 3 b, the discovered boundaries in all five boundary

categories: Individual, Domain-specific, Task-oriented, Spatial and Temporal,.and the boundary objects utilized for boundary bridging in the hackathon event phase are presented according to the nine hackathon attributes (Halvari et al., 2020).

Table 2 Pre-hackathon phase boundaries and boundary objects

Pre-hackathon activity with its aim	*Boundaries*	*Boundary objects*
Goal-setting Discover and set the multiple goals for a successful event ***Focal to boundary bridging***	**Domain-specific** Multi-domain organization Cross-functional teams *Multiple goals of stakeholders (Challenge organization, organizer, participants)*	**Goal setting document of** hackathon organizer and challenge organization incl. • hackathon organizing plan: for pre-hackathon, event and post-hackathon phases • theme and/or contest criterion • recruitment plan • prizes **Recruiting document** **Pre-defined hackathon role descriptions**
Recruiting Recruit the hackathon participants (hackers, mentors, jury) ***Focal to boundary bridging***	**Individual boundary:** **Social category of cognition** as an individual ability i.e. competence *Recruiting people from the different parts of organization with varying competences*	**Recruitment document** **Pre-defined hackathon role description**
Training of innovation and digital competence Build competence and onboard the participants acc. their hackathon roles ***Focal to boundary bridging***	**Individual boundary:** Specialized individuals with skills and expertise **Social category of cognition** as an individual ability i.e. competence *People from different parts of the organization with varying competences*	**Association exercise** with fruit to introduce oneself **Personalized Zoom backgrounds** **Teams + Zoom** platforms **Training materials** for - innovation - Teams and Zoom platform usage
Ideation and team workshop Preliminary idea generation Team building ***Focal to boundary bridging***	**Individual boundary:** Specialized individuals with skills and expertise **Domain-specific boundary** Cross-functional teams *To guide the ideas toward goals* *To support cross-functional team building*	**Theme and/or contest criterion** **Preliminary idea pitch** **Teams project cards for pitch presentation and voting**

Table 3a Hackathon attributes and boundaries

Virtual hackathon attributes	*Hackathon boundaries*	*Boundary object for bridging the boundary*
1. Goal: Multiple stakeholder goals		
Challenge organization goals - Innovation output - Organizational learning - Multi-disciplinary participants and cross-functional teams **Organizer goals** - Organize a successful event	**Domain-specific boundary** Multi-domain organization Cross-functional teams	Hackathon organizer's and challenge organization's goal-setting document incl. - hackathon organizing plan: for pre-hackathon, event and post-hackathon phases - theme and/or contest criterion - recruitment plan - prizes Recruiting document Pre-defined hackathon roles
Participator goals ***Hacker goals*** - Create and develop ideas into innovations - Collaborate and network - Participate (and win) the contest - Learn - Have fun ***Mentor goals*** - Support the hackers - Collaborate and network - Learn - Have fun ***Jury goals*** - Evaluate the innovations - Learn - Have fun	**Domain-specific boundary** Multi-domain organization Cross-functional teams	Recruiting document Pre-defined hackathon role descriptions
2. Virtual collocation	**Spatial boundary** of people in different locations	Virtual online space to communicate and collaborate Zoom + MS Teams
3. Short time bounded event	**Temporal boundaries:** - **time limitation** - Hackathon event 9 h - **specific time span** - Hackathon phases: pre-, event and post-hackathon phases Hackathon event and its phases (creation and ceremony process)	Schedule for the hackathon event - Hack-on-hack-off - scheduled mentoring sessions Schedule for pre- and post hackathon phases Schedule for the hackathon event

Source: Adopted from Halvari et al. (2020).

Table 3b Hackathon attributes and boundaries

Virtual hackathon attributes	*Hackathon boundaries*	*Boundary object for bridging the boundary*
4. Organization	**Task-oriented boundaries**	
	Boundary between hackathon roles: organizers and participants (Hackers, Mentors, Jury)	Virtual backgrounds for different hackathon roles Role channels in virtual space
5. Team	**Individual boundary**	Preliminary team name
	Social category of cognition as individual ability, competence	Team name
6. Challenge	**Task-oriented boundaries**	Hackathon theme/s Hackathon contest criteria
7. Collaboration	**Individual boundary**	Pre-defined hackathon role description
	Social category of cognition as an individual ability, competence	1st-hour list Team specific channels Open channels for collaboration
8. Creation process	**Task-oriented boundaries**	Pre-prepared virtual boards for innovation methods:
	Ideation Idea development	6 Thinking hats (De Bono, 1985) SCAMPER (Eberle, 1977) Lotus blossom (Michalko, 1991)
9. Ceremony process	**Task-oriented boundaries**	
	Result presentation of team output	Pitch & presentation
	Winner selection	Virtual voting
	Winner recognition	Ceremony presentations Prizes

Source: Adopted from Halvari et al. (2020).

Innovation Output of Virtual hackathon

Table 4 Hackathon themes and contest criteria for a virtual hackathon.

	Explanation of hackathon themes and contest criteria
Hackathon themes	
Broad theme	Agenda 2030 – municipality and residents together: Strive to involve civil society and volunteer forces in our core missions as part of strengthening the social sustainability
Focused theme	Pandemic today – what will it look like tomorrow? Develop Knivsta municipality for tomorrow with lessons learned from the implemented changes, visible challenges, and identified opportunities.
Contest criteria	
	1. Contribute positively to Knivsta municipality as an attractive employer - The idea will help strengthen Knivsta municipality in being an innovative organization where participation, commitment and clarity permeate the activities. **2. Promoting the fulfilment of the welfare mission** - The idea will help the organisation to be allowed to meet the increased welfare challenge with retained resources **3. Positive effect on the organization** - The team's approach should be realistic, and the idea should have a positive effect on the organization after implementation

In table 4, the hackathon themes and contest criteria defined by Knivsta municipality's Municipal directors' management group (MDMG) are presented. The themes acted as inspiration and contest criteria steered the innovation work of the four hackathon teams. In table 5, the innovation outputs of four hackathon teams are presented. The innovation output of all four teams was geared to the ultimate benefit of the municipality's inhabitants, thus the themes and contest criteria steered the innovation work in the sought-after direction. One of the outputs (Livslotsarna) was information service provided directly to the municipal inhabitants. Yet, the other three innovation outputs were primarily targeted at the internal development of the municipal processes. Two of them (Easy Recruit and Resursopedia) aimed at providing information services to affect

Table 5 The virtual hackathon innovation output by the teams

Hackathon team: Team compilation *Virtual hackathon innovation*
1. **Circle of Life:** 5 hackers from 4 municipal offices **Resource circle:** Municipal employees can advertise no longer needed products e.g. furniture and equipment in municipal activity, or call for needed ones **Type of innovation**: IT service provided in municipal intranet platform, circular innovation **Target:** municipal cost reduction, sustainable development acc. Agenda 2030 **Reasoning:** in Knivsta, new furniture procurement is a substantial cost approx. 0,73 MEUR in 4 years.
2. **Livslotsarna (Life pilots):** 5 hackers from 3 municipal offices **Life pilots**: information brochure and website for municipal services as well as services provided by civil society and their contact information, particularly for life´s unexpected events. The brochure is provided for every Knivsta household. **Type of innovation:** municipal information service in tangible and virtual format **Target:** the inhabitants of municipality **Reasoning:** Services provided by the municipality and civil society and contact information were not listed in a compiled manner. People faced with unexpected events, such as illness, death or unemployment do not have extra energy to look for services that would help them.
3. Easy recruit: 5 hackers from 5 municipal offices **Easy recruit -information service:** information system of compiled information on potential people for making recruiting easier **Innovation type:** Information service for recruitment **Target:** municipal organization's internal use **Reasoning:** Municipality recruit increasingly, yet information on candidates that have indicated their interest to work for a municipality is not compiled in an easily accessible way. Information on people could make recruiting a faster and more effective process.
4. Resursopedia: 6 hackers from 2 municipal offices **Resursopedia-service:** mapping and information system for sharing municipal employees' versatile competences to enhance service provision for municipal inhabitants. **Innovation type:** Information service of competence information and wide-ranging and effective HR use. **Target:** municipal organization internal use **Reasoning:** Municipality as a multi-domain organization has employees with wide-ranging competence, that can be utilized more effectively with mapped competences stored in easy-access information system.

the recruitment and competence management in the municipality. One was a circular innovation, providing information service for matching the municipality's unused furniture and equipment to those municipal services in need.

5 Discussion

The results of this article fill a prominent research gap in virtual hackathons as ICT-enabled boundary arrangements (IBSA). By answering our research question *"How is (boundary bridging) knowledge integration for innovation output carried out in a virtual hackathon as ICT-enabled boundary arrangement (IBSA)?"*, this paper makes several contributions to the innovation management theory, particularly regarding hackathons as one type of innovation contests. First, it contributes to the concept of ICT-enabled boundary arrangements (IBSAs) by clarifying the virtual hackathon as IBSA (Termeer and Bruinsma, 2016). Moreover, it contributes to the literature regarding boundaries, boundary objects, boundary bridging and knowledge integration (Star, 2010; Star and Griesemer, 1989; Tell, 2017; Van de Ven, A. H. and Zahra, 2017) in the innovation context in an intra-organizational setting by bringing new information, especially, in a virtual context. Particularly it lightens up the knowledge integration needed for innovation outputs in a virtual environment by describing the discovered boundaries in five knowledge boundary categories: 1) individual/cognitive and social boundaries; 2) domain-specific boundaries; 3) task-oriented boundaries; 4) spatial/physical boundaries; and 5) temporal boundaries (Hernes, 2004; Tell, 2017). Furthermore, it clarifies the boundary bridging in virtual hackathons as IBSAs by presenting the utilized boundary objects. Second, it contributes to the hackathon outputs and output value creation to the challenge organization (Medina Angarita and Nolte, 2020) by bringing new information especially on virtual hackathon outputs (cf. Jussila et al., 2021). Third, it contributes to the hackathon studies in the municipal organization context since most of the hackathon studies have been conducted outside any stable organizational context. Moreover, most of the intra-organizational hackathon studies and descriptions have been in the corporate context (e.g. Granados and Pareja-Eastaway, 2019; Pe-Than et al., 2020). Yet, public sector organizations have an increasing need to utilize innovation management methods, such as hackathon methodology for their innovation practice and culture development needs.

Our results to our first research sub-question *"What and of what category are the discovered boundaries in a virtual hackathon?"* show, that a virtual hackathon, one type of innovation contest, as IBSA produces multiple boundaries to be bridged in a multi-disciplinary case organization of a municipality. The pre-hackathon phase activities of Goal setting, Recruiting, Training for innovation and digital competence, and Ideation and team workshop create boundaries of two boundary categories: Individual and Domain-specific. Hackathon event itself creates boundaries of all five categories: Individual, Domain-specific, Task-oriented, Spatial and Temporal. Thus, a conclusion can be made that virtual hackathon creates a variety of boundaries in all five boundary categories to be bridged for knowledge integration to occur for innovation.

Our results to our second sub-question *"What are the boundary objects utilized for boundary bridging in a virtual hackathon?"* illustrate, that boundary objects for bridging in the pre-hackathon phase include a versatile set of objects: virtual documents for goal

setting, recruitment, and contest challenge, training materials and exercises, intangible hackathon roles and descriptions, IT-platforms with their features for collaboration and communication, and pitches. In the hackathon event phase, the boundary objects were partly new due to some additional boundaries and partly similar to pre-hackathon phase: virtual documents for goal setting, recruitment, contest challenge, schedules, pre-hackathon training materials and pre-prepared virtual boards to support collaboration intangible hackathon roles and descriptions, metaphoric of team names, IT-platforms with their features for team-based and general collaboration and communication, pitches and prizes. Of those results, it can be concluded that hackathon as one type of innovation contest does inherently consist of methods and options for boundary bridging, which in the virtual hackathon as IBSA, has to be adjusted to the options information technology provides.

Our results to our third sub-question *"What innovation outputs are resulting from the knowledge integration in the virtual hackathon as IBSA?"* portray the innovation output of boundary bridging knowledge integration in virtual hackathon. The four virtual teams produced value-adding innovations for a municipality that include information services directed to the municipal inhabitants, yet also for the internal development of the municipal processes, i.e. information services for recruitment and competence management, and circular innovation for resource reduction. Naturally, the hackathon theme and contest criteria also inspired and steered the idea generation towards the desired outcome for the municipality, yet boundary bridging with boundary objects enabled the knowledge integration for innovation.

To answer our main research question and conclude the results of our study, a virtual hackathon as an IBSA creates by its definition boundaries of all five boundary categories (Hernes, 2004; Tell, 2017), which bridging requires a multiple set of hackathon-matching boundary objects that are to be adjusted to the options provided by information technology. The boundary bridging with hackathon matching ICT-enabled boundary objects allows knowledge integration to occur in a virtual hackathon for innovation output.

From the innovation management standpoint, having a clear understanding of how knowledge integration can be carried out successfully by bridging boundaries in a virtual environment is the foundation of innovation output creation even in forced physical distance situations. Especially, practitioners aiming to enhance the organized innovation processes in their virtual events, especially in the multi-disciplinary setting, gain from this study with the presented boundary objects that help to overcome the barriers of innovation when employees work in distance mode. Therefore, the outcome of this research will benefit both academics researching innovation management methods and practitioners organizing and facilitating hackathons in virtual environments. For further research, we suggest that the virtual hackathons as IBSAs are more thoroughly investigated, especially from the viewpoint of the boundary spanners.

References and Notes

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