Multilevel boundary crossing and dialogical learning mechanisms in interdisciplinary research teams

Essi Ryymin and Laura Lamberg
HAMK Edu Research Unit, Häme University of Applied Sciences School of Professional Teacher Education, Hämeenlinna, Finland

Received 30 September 2020
Revised 9 April 2021
30 June 2021
3 September 2021
3 October 2021
Accepted 4 October 2021

Abstract

Purpose – This paper aims to reveal learning potential in crossing disciplinary boundaries in facilitated workshops by exploring the research goal definition process of interdisciplinary research teams. It uses multilevel boundary crossing as a theoretical framework to illustrate the multilevel nature of team learning mechanisms in interdisciplinary research.

Design/methodology/approach – This study uses a qualitative case study approach. The data was collected from semi-structured interviews and collaborative workshops of interdisciplinary researchers. The data analysis is based on pre-existing theory and the process of analysis is both data and theory driven.

Findings – The results indicate that although defining interdisciplinary research goals is a complex and demanding task, collaborative and facilitated workshops may support boundary crossing on intrapersonal, interpersonal and institutional levels. The team members efforts in defining their shared research interest revealed dialogical learning mechanisms of identification, coordination, reflection and the first phases of transformation, particularly at the interpersonal level. However, the transformative actions seemed to require intentional team facilitation.

Originality/value – This case study enriches the existing literature and allows better understanding of how team facilitation can promote agenda setting, transformative learning mechanisms and the definition of joint research goals in interdisciplinary settings.

Keywords Boundary, Interdisciplinarity, Boundary crossing, Team learning, Dialogical learning mechanisms

Paper type Research paper

Introduction

Responding to global challenges and complex problems in society such as rising temperatures, the growing world population and food crises requires interdisciplinary research that combines knowledge from diverse scientific disciplines. As a result, there is an increasing need to understand team learning with researchers representing more than one discipline or area of practice.

Prior research has recognised barriers associated with interdisciplinary research, including incomplete knowledge of other disciplines, their culture and values, epistemology, methodology, psychology (Bruun *et al.*, 2005), misconceptions and prejudices that scientists from different disciplines may have about each other (Campbell, 2005), as well as challenges in practical researcher collaboration (van Rijnsoevera and Laurens, 2011). Lang *et al.* (2012) state that there are crucial problems, especially in balancing research problem ownership in interdisciplinary teams.

The authors thank Annukka Pakarinen and Anna Hiltunen for their contribution to designing and collecting workshop data and Heta Rintala for her theoretical guidance.

The Learning Organization

0969-6474
DOI 10.1108/TLO-09-2020-0172

There are also several individual-, group-, institutional-and organisational-level factors that positively influence the work of interdisciplinary research teams (Tkachenko and Ardichvili, 2020) and several factors that encourage learning, such as information sharing, reducing conflict frequency and fostering a climate of psychological safety (Bunderson and Boumgarden, 2010). Zellmer-Bruhn and Gibson (2006) summarise the research literature on team learning and conclude that it includes the collective acquisition, combination, creation and sharing of knowledge and depends on both internal and external factors. In environments of constant change, teams of researchers also learn from other teams and instead of just copying best practices, learning involves interlinked and complex subprocesses of identification, translation, adoption and continuation (Bresman, 2013).

Interdisciplinarity research is portrayed as the progress of science in the combination of different theoretical and methodological perspectives appreciating the collective nature of knowledge. The source of new ideas and insights is often located at the interface of established disciplines (Bruun *et al.*, 2005) or even in crossing frontiers to form new disciplines (van Rijnsoevera and Laurens, 2011). Therefore, to fully understand interdisciplinary team learning, researchers need to investigate the structural effects on team learning and recognise both internal and external learning behaviour (Bresman and Zellmer-Bruhn, 2013). In internal learning, team members interact inside the team boundary, whereas external learning captures interactions beyond the team boundary in the context the team is embedded within (Edmondson, 1999).

The perspective of the boundary as a point of exchange emphasises the dependencies between teams and their environment and how interactions take place across boundaries. There is a need to examine collective efforts that transcend the boundaries of a single discipline (Tkachenko and Ardichvili, 2017) and factors that can act as antecedents to team boundary activity, such as sense-making mechanisms (Dey and Ganesh, 2017.) A boundary can be described as a socio-cultural difference leading to discontinuity in action or interaction (Akkerman and Bakker, 2011; Engeström *et al.*, 1995).

Two concepts are central to describing the learning potential at boundaries: boundary crossing and boundary objects. Akkerman and Bakker (2011, p. 133) define boundary crossing as a person's transitions and interactions across different sites (Suchman, 1994) and a boundary object as an artefact doing the crossing by fulfilling a bridging function (Star and Griesemer, 1989). In interdisciplinary teams, establishing a shared problem allows for the creation of a shared dynamical object, which is fundamental for managing interdisciplinary research (Alrøe and Noe, 2014).

The joint contribution of interdisciplinary researchers to research problem definition is important, as the more input into a shared purpose that the members provide, the more engaged they are likely to be during project implementation (Tkachenko and Ardichvili, 2020). However, more research is needed on researcher interaction during research problem definition. Although prior research has revealed multiple factors impacting the performance of interdisciplinary research teams, the process of interdisciplinary team learning is still not well understood (Zhang and Wang, 2020). We address this gap by applying the theoretical framework of boundary crossing and dialogical learning mechanisms to the context of interdisciplinary research.

This study aims to explore the research goal definition process of interdisciplinary research teams and reveal the learning potential in crossing disciplinary boundaries in facilitated workshops. Further, this study utilises a case study to illustrate the multilevel nature of boundary crossing in interdisciplinary research teams and encourage the practice of braver intersectoral and interdisciplinary collaboration.

Theoretical background and research questions

Several learning theories suggest that boundaries are potential resources for learning. For instance, Wenger *et al.* (2002) highlight that while boundaries are often seen as sources of potential difficulties, they also offer opportunities for radically new insights and developments. Crossing boundaries may trigger individuals, groups or larger systems to take a fresh look at their long-standing practices and assumptions. As an example, basing their theoretical approach on cultural historical activity theory (CHAT), Engeström *et al.* (1995) revealed how collaboration at the intersection of different activity systems can lead to meaning making and transformation of the involved practices.

Akkerman and colleagues (Akkerman and Bakker, 2011; Akkerman and Bruining, 2016; Akkerman *et al.*, 2012) have studied multilevel boundary crossing in the context of professional development and boundaries between teacher education, schooling and academic research, as well as in collaborative research projects between individual researchers and research groups. The researchers have revealed learning mechanisms that show several ways in which sociocultural differences in action and interaction can become resources for the development of intersecting identities and practices at boundaries. In their large literature review of previous research on boundary-crossing (2011) and empirical studies (2012; 2016), Akkerman and her team have developed the Multilevel Boundary Crossing Framework (Akkerman and Bruining, 2016, p. 246); a theoretical approach to recognise dialogical learning mechanisms: identification, coordination, reflection and transformation.

In the Multilevel Boundary Crossing Framework (Akkerman and Bruining, 2016), learning is understood broadly as developing new ways of doing or new ways of making sense of doing, triggered through collaboration or participation across multiple practices. According to Akkerman and colleagues, the four learning mechanisms of identification, coordination, reflection and transformation should not be treated as sequential or hierarchical and instead a preference for one learning mechanism over the others remains a dynamic matter influenced by the situation, time and perspective. Akkerman and Bakker (2011) highlight a Bakhtinian notion of dialogicality in the framework: Bakhtin (1981) states that all understanding and all symbolic activity of humans is "founded on dialogue between different minds expressing multitudes of multivoiced meanings" (Akkerman and Bakker, 2011, p. 136).

Identification refers to learning at the boundary in a process in which previous lines of demarcation between practices are uncertain or destabilised. Identification processes occur by defining how one practice differs from another. This dialogical process of identification can also be called othering. A second related process of identification is the underlying need for legitimating the coexistence of several intrapersonal roles. The learning potential of identification lies in a renewed sense making of different practices and related identities.

Coordination emphasises dialogue between diverse partners: means and procedures are sought allowing diverse practices to cooperate, even in the absence of consensus. Coordination requires a communicative connection and efforts of translation between different worlds and practices. Coordination also involves routinisation; the creation of automated or operational practice. The potential in a coordinative mechanism resides not in reconstructing but in overcoming the boundary, in the sense that continuity is established, facilitating effortless future movement between different sites.

Reflection means coming to realise and explicate differences between practices and learning something new about one's own practices and the practices of others. It emphasises not only comprehension but also the formulation of the distinctive perspectives. Reflection involves perspective making, that is, making explicit a person's understanding and

knowledge of a particular issue. Reflection also includes perspective taking. Taking another perspective is a way to begin to see things in a different light. Reflection results in an expanded set of perspectives and thus a new construction of identity that informs future practice.

Transformation leads to profound changes in practices, potentially even the creation of a new, in-between practice, sometimes called a boundary practice. Transformation may begin with *confrontation* with some need or problem that forces the intersecting worlds to seriously reconsider their current practices and the interrelations between them. A second process in intended and reported transformations is *recognising a shared problem space*. Akkerman and her team refer to the third-generation CHAT literature (Engeström, 2001) and use the term *boundary object* to refer to the shared problem space. Boundary objects can be defined as a "shared or jointly constructed object between two or more activity systems (Engeström, 2001, p. 136)".

An important element for recognising transformation at boundaries is hybridisation: ingredients from different contexts are combined into something new and unfamiliar. This can take the shape of new tools or signs, the formation of a new concept, an analytical model, or a new practice that stands in between established practices or an interdisciplinary field of science (Akkerman and Bakker, 2011, referring to Engeström *et al.*, 1995). Also crucial for transformation is maintaining the uniqueness of the intersecting practices and continuous joint work at the boundary.

All dialogical learning mechanisms of boundary crossing can manifest at intrapersonal, interpersonal and institutional levels. At an institutional level, actions and interactions are initiated between multiple organisations or organisational units. At the interpersonal level, boundary crossing refers to actions and interactions between specific groups of people from different practices, such as when researchers collaborate in interdisciplinary teams. Boundary crossing processes can also take place at an intrapersonal level, in which people simultaneously participate in intersecting practices and literally come to embody the boundary (Akkerman and Bruining, 2016).

This study concentrates on the boundary crossing world of a Smart and Sustainable Bioeconomy (SSB) Project of a higher education institution (HEI) that aims to combine expertise and perspectives from various disciplines to generate sustainability innovations through data-driven knowledge creation. The specific interest is at the early stages of a Smart Vertical Farming (SVF) project (Al-Chalabi, 2015). Strategic goals of the SVF project include responding to the need for sustainable food production by implementing data analysis and optimising biomass production in the controlled conditions of a container farm. The interdisciplinary research teams include researchers from natural sciences and digital, technological and educational domains. At the first phase of SVF, interdisciplinary teams define and deliberate their shared research interests.

The objective of this study is to seek answers to the following research questions in the theoretical framework of Multilevel Boundary Crossing (Akkerman and Bruining, 2016, p. 246):

RQ1. What kind of dialogical learning mechanisms can be recognised in the discourse of interdisciplinary teams of the SVF project in the phase of defining the shared research interest?

RQ2. At what levels – institutional, interpersonal, intrapersonal – does boundary crossing take place in the process?

Additionally, the aim is to investigate the development of interdisciplinary teams in the process of shared research interest deliberation and to find answers to the question:

RQ3. How did the dialogue and learning mechanisms evolve during the research process?

Data collection and method

The data of this study was gathered in the SVF project – a sub-project of a larger sustainable and smart bioeconomy development project and initiative by an HEI. The main data for this case study consists of the three (3) interdisciplinary team workshops that were organised for researchers for deliberating their shared research interest of SVF. Two of the workshops were organised face-to-face and one as an online meeting. The process of organising the virtual workshop also included five preparatory semi-structured interviews with four researchers and one industry partner. The participants of the workshops represented different research units of the HEI, which we will name for the purpose of this paper Natural Sciences, Technical Sciences, Digital Solutions and Educational Sciences. The backgrounds of the researchers included different sub-disciplines within these units, including bioprocess and automation engineering, horticulture, data science and chemistry. All workshops were recorded and the recordings were transcribed. An analysis of the workshop material also benefitted from comprehensive data of the larger SSB development project, including 11 semi-structured interviews with interdisciplinary researchers as well as documentation of the planning meetings of the team workshops. Table 1 provides an overview of the available research material.

Overview of the interdisciplinary team workshops

As the SVF is a bioeconomy development and innovation initiative, researchers from the Natural Sciences research unit of the HEI contributed to the process with the greatest effort. This leading role of the Natural Sciences unit was echoed across the board in mapping interviews with key project researchers: the unit was considered the most crucial for defining the substance of the research project. The Natural Sciences research unit had been established quite recently, a couple of years prior to the study and the unit had recently recruited new researchers. Hence, the first workshop "Brainstorming Interdisciplinary Research Interests" was mostly for researchers from the Natural Sciences research unit. However, it is important to understand that within the broad range of the natural science field, researchers represented different sub-disciplines and degree programmes and some of them did not know each other before the joint SVF project. Additionally, a researcher from the Technical Sciences research unit participated in the workshop to begin establishing the collaborative connection between the units. The planning of the workshop was based on the analysis of researcher expectations for interdisciplinary collaboration related to SVF (Ryymin *et al.*, 2020) and its goal was to brainstorm the first ideas for SVF research by implementing facilitated group dialogue methods. Altogether, there were seven participants in the workshop. The workshop lasted 117 min and the brainstormed research ideas were collected together on post-it notes.

The first workshop produced many possible research ideas and pathways, for which further elaboration and prioritisation of initiatives were needed. The second face-to-face workshop "Prioritising Research Interests" was organised with the aim of prioritising the research ideas with the support of a digital platform for assessing, voting and sorting the research interests (Ryymin *et al.*, 2020). This time, the facilitators of the workshop, two researchers, came from the Educational Sciences research unit. The facilitators guided the prioritisation process by putting the strategy and mission of the SSB project and the HEI on the agenda. In addition to the facilitators, there were six participants in the workshop, five from the Natural Sciences unit and one from the Technical Sciences unit. The workshop lasted 105 min and the prioritised research ideas were collated on the database of the digital platform.

Data Collected	Interest	Data considered in this study	Details of the included data
Mapping Interviews	Researcher backgrounds and discipline and expectations of interdisciplinary collaboration in SSB and SVF		Semi-structured interviews of 11 researchers
Team Workshop 1	Team learning mechanisms in brainstorming phase of SVF research interest	X	Audio recording of workshop (117 min) 7 participants Post-it notes
Team Workshop 2	Team learning mechanisms in prioritization phase of SVF research interest	X	Audio recording of workshop (105 min) 8 participants Digital group decision making platform database
Mapping Interviews for Team Workshop 3	Team Workshop 3 participant backgrounds, discipline and expectations of interdisciplinary collaboration in SVF	X	Semi-structured interviews of 4 researchers and 1 industry partner
Team Workshop 3	Team learning mechanisms in design and implementation phase of SVF research interest	X	Online video recording of workshop (94 min) and small group recordings (25 min, 25 min and 24 min)
Planning Material for Team Workshops	Project manager and facilitator interaction and their joint goal setting, implementation methods and assessment of SVF workshops	X	Written memos and notes of planning and assessing the workshops
Observations	Researcher collaboration and interaction in their SSB project meetings and in field experiments		
Overall Project Documentation	Development and challenges of interdisciplinary collaboration in SSB-project		

Table 1. Overview of data sources

Preparation of the third team workshop included individual semi-structured interviews of four researchers and one industry partner involved in the SVF project. Two of the researchers were from the Natural Sciences unit and the other two from the Technical Sciences unit. The goal of the interviews was to gain knowledge of the background of workshop participants and insights of their expectations for the interdisciplinary collaboration. The interviews lasted from 38 min to 55 min and were recorded and transcribed.

The third workshop "Design and Implementation of Research Ideas" was organised virtually due to Covid-19. There were altogether 12 participants in this workshop including 3 facilitators from the Educational Sciences unit. The workshop included group collaboration between all participants and separate sessions in three small groups. There were four participants in each group: a facilitator from the Educational Sciences unit and researchers representing the Natural Sciences, Technical Sciences and Digital Solutions. The goal of the workshop was to further develop research ideas and their implementation in SVF

by intentionally enriching the ideas with perspectives, methods and standards from different disciplines. The role of the facilitators was to keep this goal on the agenda and to encourage the participants to conceptualise and reconceptualise (Engeström *et al.*, 1997) the joint interests. The workshop participants wrote their shared ideas on digital post-it notes, which were shared and saved for future use. Figure 1 illustrates the research units, workshop participants and facilitators of the workshops.

Method for data analysis

This case study implements a thematic analysis as described by Braun and Clarke (Braun and Clarke, 2006; Terry *et al.*, 2017) in the workshop data analysis, which was an iterative, theory- and data-driven process conducted by the authors. A qualitative research design was chosen with the goal of analysing discussion and dialogue and to gain in-depth insights into the complex nature of learning and interaction at multiple levels in interdisciplinary teams. The codes of analysis were designed based on the pre-existing theory of the Multilevel Boundary Crossing Framework (Akkerman and Bruining, 2016, p. 246). The unit of analysis was a thematic episode, a comment, or a piece of discourse by workshop participants. These were constructed around a certain theme from the Multilevel Boundary Crossing Framework. Each thematic episode contained one identified dialogical learning mechanism at an institutional, interpersonal, or intrapersonal level. There were altogether 379 thematic episodes identified in the team workshop data.

Results

The analysis of the 11 mapping interviews revealed that the researchers in the SSB development project had positive expectations towards the joint work. For instance, they presumed solutions would be sought for sustainability, new competences and the strategic development of scientific research in the HEI (Ryymin *et al.*, 2020).

First team workshop

The analysis of discourse in the first team workshop "Brainstorming Interdisciplinary Research Interests" revealed a strong emphasis on *identification and coordination at the*

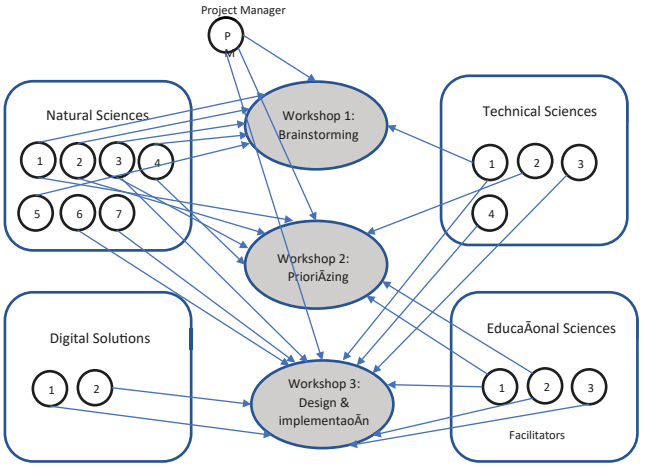

Figure 1. Visualization of research units, workshop participants and facilitators

interpersonal level. The participants of the workshop expressed interpersonal identification by defining their different and complementary research interests and specialties, as shown in Excerpt 1. They also defined and refined the duties of different teams and individuals and described how they differed from each other. There were also expressions of identification at the intrapersonal level, for instance, the researchers discussed personal interests and introduced their duties and latest initiatives. In addition, they also wanted to emphasise the things they did not know or fully understand, often in humorous ways.

Excerpt 1 (1B, identification at the interpersonal level):

Researcher 1: "In Biotechnology and Food Engineering, do you [. . .]?"

Researcher 2: "So grapes?"

Researcher 3: "Grapes, their [. . .]."

Researcher 1: "Do you teach tasting in Food Engineering?"

Researcher 2: "Yes we do sensory evaluation."

Researcher 3: "It's just one level to it."

Researcher 2: "It's the easiest level to start with before there's some numbers in some analyser that no one really understands."

The discourse that reflected coordination at the interpersonal level included attempts by the participants to find a communicative connection with each other. The participants translated their routines and practices and actively sought possibilities to co-operate. However, this dialogue concerning collaboration included mainly aspects of organising current practicalities, not co-developing new approaches, as shown in Excerpt 2. The participants listed several research interests in the workshop, but they did not elaborate the research pathways from the new or different perspectives. The ideas echoed their diverse practices as researchers from different disciplines. They also find no consensus of the research interests.

Excerpt 2 (2B, coordination at the interpersonal level):

> Yes, we need to think about what kind of data we could collect, [–] what data could be nice to collect, what could be useful for developing the process. [–] Then we need to keep the realities in mind, what is possible, do we know what's possible, should we experiment with something? And then the realities of how and in what time frame, what we need to be able to do and then maybe a plan for what comes first.

In line with Hillersdal *et al.* (2020), the analysis of the first workshop revealed that involvement in interdisciplinary research presses researchers to navigate very different standards, obligations and requirements and a great deal of mutual explanations are needed. However, the possible learning potential of the workshop lay in "overcoming the boundary in the sense that continuity is established" (Akkerman and Bakker, 2011, p. 146) and in the renewed sense making of different practices.

Second team workshop

In the second team workshop "Prioritising Research Interests", the participants continued their attempts to find a communicative connection with each other and the dialogical learning mechanism of *coordination at the interpersonal level* was still actively maintained. However, in this workshop the participants started to mutually define the different perspectives of their research interests and what intersecting practices could bring to the agendas. The participants expressed mutual appreciation and took up perspectives of others regarding the project, as exemplified in excerpt 3. This dialogue mirrored the learning mechanism of *reflection at the interpersonal level*. Possible explanations for this change might be that, firstly, the process of prioritisation itself urged the participants to explain and

expand their perspectives. Secondly, the facilitators of the workshop actively guided the participants to adopt new perspectives and further, they encouraged cross-sectoral dialogue and openness.

Excerpt 3 (3B, reflection at the interpersonal level):

> The best thing [to come out of the workshop] was that, it was nice to hear what other people are thinking about. And it was great to recognise that we don't all think in the same way, because that leads nowhere. This kind of conversation in incredibly good, because you receive these different perspectives, different insights. And there's lots more. We have here concrete things too [indicates the results of research idea prioritisation]. Something that we can continue chewing on in the next meetings.

The facilitators also brought the strategy and mission of the HEI and the SSB project to the agenda with the aim to help the team find guidelines and inspiration for the current research challenges from these frameworks. The frameworks stimulated the participants to reflect on the mission, values and goals of the HEI and research units and the conversation expressed *identification at an interpersonal and institutional level*, as shown in Excerpt 4. The team workshop collaboration produced a concrete, prioritised list of research interests and a digitally supported prioritisation method helped the interdisciplinary process scientifically (Ryymin *et al.*, 2020). While identification represents a focus on a renewed set of practices and the reconstruction of current identity, the learning potential of reflection results in an expanded set of perspectives and thus a possibility for the re-construction of identity (Akkerman and Bakker, 2011).

Excerpt 4 (1 A, identification at the institutional level):

> We can also define a more societal meaning for it [smart vertical farming], related to, you know, saving the world and Africa and stuff like that. But in a way that's controlled, or that can first be tested, before it gets out of hand to the level of communities and non-organised actors. [Our HEI] implements applied research, which generates new and creative solutions. They have to be new and creative, or we wouldn't be funded, if the solutions have already been found somewhere else.

Third team workshop

According to the mapping interviews of the participants of the third workshop "Design and Implementation of Research Ideas" the researchers were eager to collaborate with their colleagues on shared research interests. However, they did not quite know what to expect from the collaboration. The researchers from the Unit of Technological Sciences and Digital Solutions expressed their willingness to "follow the wish list from the Natural Sciences unit", but their own role in defining the research interest was unclear.

In the third workshop, the facilitators played a crucial role; they intentionally guided the group dialogue between different research units. They also encouraged the participants to define and refine the research interests with the aim to find something new and innovative. The goal in small group collaboration was to ambitiously combine approaches from all the research units to the research agenda and implementation plan. It is good to recognise that there were some new researchers joining in the process and for the first time, from the Digital Solutions unit as well. However, the newcomers were well informed of the project and its goals and they had already worked in other SSB subprojects.

The analysis of the third workshop revealed that the participants took up each other's perspective to look at the research interests related to SVF and thus engaged in boundary crossing and *reflection at the interpersonal level*. Interestingly, they also recognised the research interest as a shared problem space and started to create new, in-between research pathways. These intentions can be interpreted as first efforts towards *transformation at an*

interpersonal level. The shared object, a research interest, played a crucial role as a boundary object (Engeström, 2001) in the process. While elements of identification and coordination of distinct research interests remained, the interdisciplinary debate of the workshop also gave some first hints of the possible hybridisation of perspectives and crystallisation of new ideas in terms of new research and implementation plans.

The team workshop participants were intermittently involved in interaction in which they focused on a shared problem, trying to find mutually acceptable ways to conceptualise and define the shared research interest. The did this instead of each focusing on performing their own roles or presenting themselves. In a similar process, Engeström *et al.* (1997) uses the term "reflective communication", wherein both the object and the script of communication are reconceptualised, as it was in the interaction between the participants in our study.

The workshop produced ideas and implementation plans that could be transformative if put into action. In contrast with the other mechanisms, transformation can entail the emergence of new in-between practices. Transformation is very difficult to achieve in practice, but if successful, it also implies sustained impact, which is why most intervention studies aim for this transformational type of dialogical learning (Akkerman and Bakker, 2011). Hints of transformation are echoed in the words of a researcher from the Technical Sciences Unit in Excerpt 5:

Excerpt 5 (4B, transformation at the interpersonal level):

> Both of you (researchers from the Natural Sciences Units) mentioned food production and we have thought about this a bit. You know, the smart green walls that we were talking about, besides being aesthetic, to reduce harmful chemicals in the air. But could we do something like that with edible food plants? Well that's been an idea in our research group for maybe, you could say for several years, but it's sort of been left to the side because we don't have that plant expertise and somehow we haven't known how to grab a hold of it. [–] I don't know these issues very well, but there could be something interesting there because there are a lot of indoor air challenges in construction that we struggle with.

Intentional facilitation possibly explains the change from reflection to transformation and the overall development of dialogical learning mechanisms in the workshops. Figure 2 gives an overall view of the boundary crossing levels and dialogical learning mechanisms identified in Team Workshops 1, 2 and 3 following the Multilevel Boundary Crossing Framework by Akkerman and Bruining (2016).

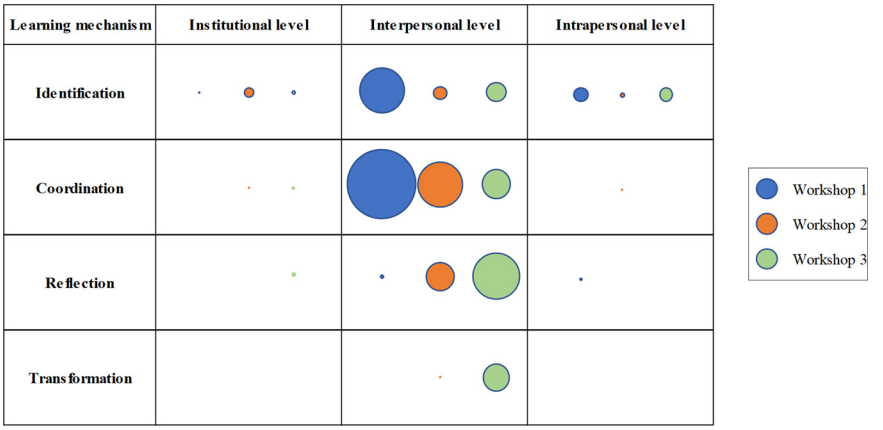

Figure 2.
Boundary crossing levels and dialogical learning mechanisms identified in Team Workshops 1, 2 and 3

Discussion

In this case study, we asked three research questions:

RQ4. What kind of dialogical learning mechanisms can be recognised in the discourse of interdisciplinary teams of the SVF project in the phase defining the shared research interest?

RQ5. At what levels – institutional, interpersonal, intrapersonal – does boundary crossing take place in the process?

RQ6. How did the dialogue and learning mechanisms evolve during the research process?

Firstly, the study found that dialogical learning at boundaries was present in all four mechanisms of the boundary crossing framework: identification, coordination, reflection and transformation. Coordination was the most emphasised mechanism. This result is in line with earlier research (Akkerman and Bruining, 2016), which suggests that a tendency towards coordination shows an understandable pragmatic approach to integrating research on the boundaries of different disciplines.

Secondly, our results emphasised the interpersonal level. This result is contrary to Akkerman and Bruining's (2016) findings, which underline the intrapersonal level. We believe this difference has much to do with the respective methods of our studies. Akkerman and Bruining based their results on interview data which gives more room for the articulation of introspection, whereas our data relies on workshop discussions between several researchers. Based on our case study, it seems that interpersonal relations between researchers, as well as personal interests, experience and values are highlighted in interdisciplinary research collaboration and teamwork sessions. Furthermore, while disciplinary differences between research units at the institutional level were occasionally discussed and explicitly reflected upon, it seems that disciplinary differences manifest strongly in terms of individual lived experience. Negotiations of interdisciplinary differences and the "disciplinary positioning" (Hah, 2020) researchers engage in are fluid and largely dependent on the personas and communication competence (Leigh Thompson, 2009) of those involved. This is both a benefit and a challenge for interdisciplinary research.

Thirdly, our case study found that boundary crossing in interdisciplinary research resulted in very different learning mechanisms depending on the design and facilitation of each workshop interaction. Although the four learning mechanisms in the multilevel boundary crossing framework are not in themselves hierarchical, as intended by Akkerman and Bruining (2016), the results of this study show a loose pattern starting from identification and coordination, followed by stronger reflection and attempts at transformation. The question remains whether this chronology was more a result of organic development in team dynamics or manufactured by the facilitation process and design of the workshop series.

Conclusions, implications and limitations

To conclude, this study provides insight into learning mechanisms in an interdisciplinary team of researchers working to define a shared research interest. Due to the interdisciplinary nature of our research case, transformation and the related formation of boundary objects through a shared research problem was of particular interest. Importantly, the results give distinct hints at transformational learning, although in real-life practice this does not necessarily translate into immediate, lasting transformation.

Contrary to Akkerman and colleagues (Akkerman and Bakker, 2011; Akkerman and Bruining, 2016; Akkerman *et al.*, 2012), our findings suggest a sequential tendency in learning mechanisms, moving from identification and coordination towards reflection and transformation when interdisciplinary teams gather for multiple facilitated sessions. Based on this case study, there are implications of the impact of facilitation and workshop design on advancing transformative learning mechanisms. Transformative learning mechanisms were intentionally reinforced by the facilitators of the workshops, with the third workshop most deliberately facilitating transformation. However, it is unclear in this study how much is the product of facilitation and which effects could be traced back to more organic team development. While prior research has revealed that group work design has an impact on idea sharing by interdisciplinary research groups (Todorova *et al.*, 2020), more research is needed to understand the effects of group work facilitation on learning mechanisms at boundaries. Based on our study, we propose facilitation and group work design to be given more resources in research planning processes and other interdisciplinary or multisectoral team learning processes. As an example, we suggest research teams to take actions for getting to know each other's research interests and methods, such as peer-shadowing.

We also found the significance of the interpersonal level in our interdisciplinary group of researchers to be surprisingly pronounced. The recognition and negotiation of interpersonal differences and similarities in research interest, values and background formed a major backbone of the interdisciplinary group work, while appeals to more institutionalised disciplinary difference were far less prominent. This finding reinforces the need to take time to build working interpersonal relations in interdisciplinary or multisectoral teams. Related perspectives to interdisciplinary team learning are also promising areas for further research, such as recent research on personal feelings and affective tensions in interdisciplinary research (Hillersdal *et al.*, 2020) as well as attitudes and behaviours contributing to or working against interdisciplinary research (Tkachenko and Ardichvili, 2020).

This case study has some limitations. Firstly, the sample is small and gathered from one organisation and was conducted in limited research settings. Secondly, it is challenging to present a realistic picture of the complexity of interdisciplinary research collaboration by writing. There may be several different ways to present the same set of issues and this brings challenges to summarising the study results.

Future studies are needed of learning in boundary crossing research teams. Especially, new perspectives are required to understand the dynamic recursion (Kodama *et al.*, 2017) of interdisciplinary teams from the phase of research interest formulation to the transformation of research and emergence of innovations. Longitudinal research designs on the development of boundary crossing activity in multisectoral teams working together over longer periods of time would be particularly valuable. Additionally, in the future, research into intersubjectivity (Welton, 1999) may offer new insights into overcoming boundary crossing challenges.

References

Akkerman, S. and Bakker, A. (2011), "Boundary crossing and boundary objects", *Review of Educational Research*, Vol. 81 No. 2, pp. 132-169.

Akkerman, S. and Bruining, T. (2016), "Multilevel boundary crossing in a professional development school partnership", *Journal of the Learning Sciences*, Vol. 25 No. 2, pp. 240-284.

Akkerman, S., Admiraal, W. and Simons, P.R.J. (2012), "Unity and diversity in a collaborative research project", *Culture and Psychology*, Vol. 18 No. 2, pp. 227-252.

Al-Chalabi, M. (2015), "Vertical farming: skyscraper sustainability?", *Sustainable Cities and Society*, Vol. 18, pp. 74-75.

Alrøe, H.F. and Noe, E. (2014), "Second-order science of interdisciplinary research: a polyocular framework for wicked problems", *Constructivist Foundations*, Vol. 10 No. 1, pp. 65-76.

Bakhtin, M. (1981), "Discourse in the novel", in Holquist, M. (Ed.), *The Dialogical Imagination*, University of TX Press, Austin, pp. 259-422.

Braun, V. and Clarke, V. (2006), "Using thematic analysis in psychology", *Qualitative Research in Psychology*, Vol. 3 No. 2, p. 77.

Bresman, H. (2013), "Changing routines: a process model of vicarious group learning in pharmaceutical R&D", *Academy of Management Journal*, Vol. 56 No. 1, pp. 35-61.

Bresman, H. and Zellmer-Bruhn, M. (2013), "The structural context of team learning: effects of organizational and team structure on internal and external learning", *Organization Science*, Vol. 24 No . 4, pp. 1120-1139.

Bruun, H., Hukkinen, J.I., Huutoniemi, K.I. and Thompson Klein, J. (2005), *Promoting Interdisciplinary Research: The Case of the Academy of Finland*, Edita oy, Helsinki.

Bunderson, J.S. and Boumgarden, P. (2010), "Structure and learning in self-managed teams: why 'bureaucratic' teams can be better learners", *Organization Science*, Vol. 21 No. 3, pp. 609-624.

Campbell, L.M. (2005), "Overcoming obstacles to interdisciplinary research", *Conservation Biology*, Vol. 19 No. 2, pp. 574-577.

Dey, C. and Ganesh, M.P. (2017), "Team boundary activity: a review and directions for future research", *Team Performance Management: An International Journal*, Vol. 23 Nos 5/6, pp. 273-292.

Edmondson, A. (1999), "Psychological safety and learning behavior in work teams", *Administrative Science Quarterly*, Vol. 44 No. 2, pp. 350-383, availabel at: https://doi. org/10.2307/2666999.

Engeström, Y. (2001), "Expansive learning at work: toward an activity theoretical reconceptualization", *Journal of Education and Work*, Vol. 14 No. 1, pp. 133-156.

Engeström, Y., Engeström, R. and Kärkkäinen, M. (1995), "Polycontextuality and boundary crossing in expert cognition: learning and problem solving in complex work activities", *Learning and Instruction*, Vol. 5 No. 4, pp. 319-336.

Engeström, Y., Brown, K., Christopher, L.C. and Gregory, J. (1997), "Coordination, cooperation and communication in the courts: expansive transitions in legal work", in Cole, M., Engeström, Y. and Vasquez, O. (Eds), *Mind, Culture and Activity: Seminal Papers from the Laboratory of Comparative Human Cognition*, Cambridge University Press, Cambridge, pp. 369-385.

Hah, S. (2020), "Valuation discourses and disciplinary positioning struggles of academic researchers: a case study of 'maverick' academics", *Palgrave Communications*, Vol. 6 No. 1, p. 2.

Hillersdal, L., Jespersen, A.P., Oxlund, B. and Bruun, B. (2020), "Affect and effect in interdisciplinary research collaboration", *Science and Technology Studies*, Vol. 33 No. 2, pp. 66-82.

Kodama, M., Yasuda, T. and Hirasawa, K. (2017), "Ma thinking and innovation in global high tech companies: the lessons of business model innovation in apple and cisco systems", in Kodama, M. (Ed.), *Ma Theory and the Creative Management of Innovation*, Palgrave Macmillan, New York, pp. 43-80.

Lang, D.J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M. and Thomas, C.J. (2012), "Transdisciplinary research in sustainability science: practice, principles and challenges", *Sustainability Science*, Vol. 7 No. S1, pp. 25-43.

Leigh Thompson, J. (2009), "Building collective communication competence in interdisciplinary research teams", *Journal of Applied Communication Research*, Vol. 39 No. 3, pp. 278-297.

Ryymin, E., Lamberg, L. and Pakarinen, A. (2020), "How to digitally enhance bio economy collaboration: multidisciplinary research team ideation for technology innovation", *Technology Innovation Management Review*, Vol. 10 No. 11, pp. 31-39.

Star, S.L. and Griesemer, J.R. (1989), "Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's museum of vertebrate zoology, 1907–39", *Social Studies of Science*, Vol. 19 No. 3, pp. 387-420.

Suchman, L. (1994), "Working relations of technology production and use", *Computer Supported Cooperative Work*, Vol. 2 Nos 1/2, pp. 21-39.

Terry, G., Hayfield, N., Clarke, V. and Braun, V. (2017), "Thematic analysis", in Stainton Rogers, W. and Willig, C. (Eds), *The SAGE Handbook of Qualitative Research in Psychology (2nd)*, SAGE Publications, London, pp. 17-37.

Tkachenko, O. and Ardichvili, A. (2017), "Cultural-historical activity theory's relevance to HRD: a review and application", *Human Resource Development Review*, Vol. 16 No. 2, pp. 135-157, doi: 1534484317696717.

Tkachenko, O. and Ardichvili, A. (2020), "Critical factors impacting interdisciplinary university research teams of small size: a multiple-case study", *Team Performance Management: An International Journal*, Vol. 26 Nos 1/2, pp. 53-69.

Todorova, G., Brake, M.R.W. and Weingart, L.R. (2020), "Work design and task conflict in interdisciplinary groups", *International Journal of Conflict Management*, Vol. 31 No. 4, pp. 623-646.

van Rijnsoevera, F.J. and Laurens, K.H. (2011), "Factors associated with disciplinary and interdisciplinary research collaboration", *Research Policy*, Vol. 40 No. 3, pp. 463-472.

Welton, D. (Ed.) (1999), *The Essential Husserl: Basic Writings in Transcendental Phenomenology*, IN University Press, Bloomington, IN.

Wenger, E., McDermott, R. and Snyder, W.M. (2002), *Cultivating Communities of Practice*, Harvard Business School Press, Boston, MA.

Zellmer-Bruhn, M. and Gibson, C. (2006), "Multinational organization context: implications for team learning and performance", *Academy of Management Journal*, Vol. 49 No. 3, pp. 501-518.

Zhang, X. and Wang, X. (2020), "Team learning in interdisciplinary research teams: antecedents and consequences", *Journal of Knowledge Management*, Vol. 25 No. 6, pp. 1429-1455.

Corresponding author
Essi Ryymin can be contacted at: essi.ryymin@hamk.fi