FACILITATING MUTUAL LEARNING IN LIVING LABS VIA DEVELOPING PROFESSIONAL IDENTITY OF KNOWLEDGEABILITY IN DAILY COMMUNICATION

A case study on a living lab of sustainable medical instruments

By Weiwei Liu

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Delft University of Technology

Thesis committee

Dr. Ir. Steven Flipse

Dr. Ir. Tim Horeman

Drs. Caroline Wehrmann

Prof. Dr. Marc de Vries

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“When you know a thing, to hold that you know it; and when you do not know a thing, to allow that you do not know it; this is knowledge.”

—Confucius,
The Analects of Confucius

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Summary

The living lab methodology is an approach to realise the innovation process by bringing together users, technology and business for collective ideation in a real-life environment. This study looked into the human level of the boundary-spanning activities within a living lab group via a case study on a university living lab of medical devices. This research aimed to provide insights on the interpersonal interaction to optimise the mutual learning between participants of a university living lab. The results of this research were translated into a communication tool to realise the optimal mutual learning within a living lab context.

This research found out that the identification process played an important role in facilitating users to obtain benefits of the boundary-spanning activities while mitigating the possibility of conflicts. In the process of dynamic formation of professional identity in a living lab context, various identities of competence come closer and intersect with each other. The supervenient overlapping area of different competence can be regarded as the identity of knowledgeability. Knowledgeability manifests the ability to see the relevance of other competence to a professional's own competence. Translated into practice in the design process of medical devices, the identity of competence provides a feasibility scope of expertise, which makes sure the design decision would be viable in the future commercialisation according to a certain aspect. Actors with knowledgeability to all the expertise in a group can better tweak the decision into the overlapping area of all the feasibility scopes of expertise, for example, of clinical, engineering and commercial expertise in this case. This research suggests that knowledgeability could be an indicator of so-called boundary-spanning competence.

Knowledgeability is the result of identification in the interdisciplinary interaction within a living lab context. When designing a tool to facilitate the acquisition of knowledgeability, this study utilised the three modes of identification, namely imagination, engagement and alignment as the foundation of the tool. The tool stimulates reflection of the users through a series of inspiring questions and guides the users to reap the benefits of daily interdisciplinary conversations through communicative solutions.

The main recommendations for future research entail taking this preliminary tool as a starting point to explore the cognitive activities further when people engage in boundary-spanning activities and the psychological aspect of the identification process. Furthermore, defining the quantitative criteria of knowledgeability would greatly improve the reliability and usefulness of the tool.

Lists of definitions

Boundary-spanning activities: are the activities that happen in a context where actors with various backgrounds and expertise try to collaborate and learn across their boundaries.

Causal loop diagram: is a causal diagram that aids in visualising how different variables in a system are interrelated.

Community of practice: are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly.

Critical node: is the most influential node in a causal loop diagram, and serves as a tool to identify the communication and collaboration related problem in the case study.

Customer companies (CC): are usually bigger companies which directly develop new solutions or products to end-users.

Enable technology companies (ETC): are the suppliers of enabling technology. These companies have certain technology or solutions that can be applied in production. And these companies wanted to bring their knowledge from academic into the markets by offering solutions to bigger customer companies.

Feasibility scope of expertise: describes the feasible limitations of every expertise. The decision in a multidisciplinary group should be made within all the feasibility scope of expertise. Feasibility scope of expertise is the practical representative of identity of competence applied in the multidisciplinary group.

Identity of competence: is the understanding of what the competence as a professional is and what expertise a professional applies in a multidisciplinary group is

Knowledgeability: manifests the abstract relations to the landscape. Knowledgeability indicates that people cannot be competent in all the expertise that were brought in the group, but all the participants can be knowledgeable about all the expertise of the others in the group and the relevance of this expertise to their own practice.

Living lab: an approach to realise the innovation process by bringing together users, technology and business for collective ideation in a real-life environment.

Metacognition: metacognitive knowledge makes people aware of the possibilities and limitations of their own cognitive abilities. It is an aspect of professionalisation.

Professional identity: is the commitment to perform competently and legitimately in the professional context.

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01 Introduction

In this chapter, the foundation of this research is laid out. This chapter introduces the research and its context, and gives a glimpse of the structure and used approach of this report.

1.1 Backgrounds

The current healthcare system is increasingly challenged by several societal issues, including an aging population, an increase of unmet medical needs and rising healthcare costs. These issues significantly influence the sustainability of healthcare systems (Janssen & Moors, 2015). Thus, the need for better solutions, which aim to accelerate introducing healthcare solutions to society while reducing its cost, draws worldwide attention in the healthcare sector (Collins & Dempsey, 2019). The solutions may come from the knowledge provided by research: innovations that translate knowledge into products that actually benefit society, in this case, by improving healthcare. Innovations lie in the centre of academia, and knowledge institutes generate high-quality intellectual properties on a large scale (Sanami et al., 2017). However, discussions on the failure of European research institutes in converting their strength in scientific research into successful innovations in the market (European Commission, 1995) continue to exist. According to Argyropoulou et al. (2019), there is no doubt that European institutes produce high-quality and high volume basic scientific research. However, a question remains unsolved regarding how can European firms and industries benefit from these researches from their knowledge institutes. The role of European universities and research centres is critical. During the improvement of the healthcare system, universities need to exchange knowledge with industries and government and bridge the research to market. Namely, there is a demand for collaboration and translation of knowledge between various sectors, including industries, universities and policy-makers, in the innovation process (Kitson et al., 2018).

Nowadays, innovations are not the outcome of the isolated efforts of a certain company anymore. A higher degree of novelty in product innovation comes from networks comprising various partners (Nieto & Santamaría, 2007). Along with the development of the regulation of intellectual property (IP) rights in the last two decades (Mowery et al., 2004), universities have shown more active involvement in the business world (Geuna & Muscio, 2009). It is found that universities with stronger scientific productivity seem to be advantageous in developing entrepreneurial activities, such as patenting activities, spin-off activities and contract research (Van Looy et al., 2011). The current issue is how to improve the interaction between universities and their business relations under the pressure of a stronger knowledge economy (Mustar et al., 2008). Meanwhile, many entrepreneurs acknowledged that the current healthcare system is not supportive enough for radical innovation. Among their various entrepreneurial strategies, they indeed appreciated the added values of developing innovations in an interactive system context (Janssen & Moors, 2015).

Under this circumstance, there are two paradigms of innovation which study collaborative innovation from a different perspective. The open innovation takes the perspective of firms and studies the financial benefits of utilising the input of external actors or parties of their own innovation (West & Bogers, 2014). By comparison, the user innovation addresses the innovation process from the perspective of the users, especially to explore how users can actively involve and constructively contribute to innovation (Hippel, 2005). On the basis of these two paradigms of innovation, the living lab methodology is defined as an approach to realise the innovation process by bringing together users, technology and business for collective ideation in a real-life environment (Hossain et al., 2019; Keyson et al., 2017). It was argued that living labs methodology bridging the different emphasis of open and user innovation, in which open innovation can be used to study the knowledge transfer within the context, while user innovation can provide insights into user involvement (Schuurman, 2015). Despite differences in setting, subject and size, living labs share the following characteristics (van Geenhuizen & Guldemond, 2013):

- An early engagement of the user group
- Experiment ideas in a real-life environment
- An open network which brings together stakeholders with the common desire of quicker and better innovation in the market

There are various positionings and categories of living labs. One of the methods to categorise living labs is based on the involvement of users, as active co-creators or as passive subjects (Almirall et al., 2012). In the academic context, living labs have become increasingly popular strategies for the co-production of knowledge. In university living labs, questions are co-created through consultation between non-academic and academic stakeholders, and working in this way maximises the benefit of knowledge produced to non-academic stakeholders (Evans et al., 2015). The philosophy of the living lab activities is to enable collaborative learning among users, researchers and industries (van Geenhuizen, 2018). In this course, learning is the key process, especially for problem-based and engineering learning types, which aims to find solutions to human problems (Asheim et al., 2007). This type of learning gives greater motivation for collaborative learning between various actors to speed up the innovation process (van Geenhuizen, 2013). Under this circumstance, the academic living labs, which bridge the researchers and stakeholders with more economic and societal impacts, increasingly draw attention nowadays as a promising approach to facilitate the translation of knowledge into applications and enhance the societal role of universities (Breznitz & Feldman, 2012).

1.2 A research gap and scope of this thesis

The current research about living labs describes a comprehensive picture of the concurrent innovation process and in which living labs function as a bridge between market pull and technology push innovation (Hronszky & Kovács, 2013). Besides exploring the role of living labs in an open innovative development process, most of the literature study about living labs focus on a managerial level. The roles of various actors were explored and characterised (Nyström et al., 2014), especially the role and significance of users in living labs (Hippel, 2005). The characteristics of living labs and the vision and mission of living labs are also popular research topics. According to Hossain (2019), the success of a living lab depends on the ability to transfer knowledge between different parties. Furthermore, outcomes of living labs are also influenced by the quality of the learning processes and a broader networking (De Moor et al., 2010; D'Hauwers et al., 2017). Based on this research, there are already a few frameworks (van Geenhuizen, 2018; Logghe & Schuurman, 2017), indicators (Turgut & Katzy, 2012) and process models (Guzmán et al., 2013; Bresman, 2012) available to evaluate the operation of a living lab from a holistic point of view.

As mentioned before, the success of a living lab depends on the learning across boundaries between different parties (Hossain et al., 2019), and individuals conduct the learning process. However, there is a lack of tools that facilitate the human interaction between people who actually work together and experience the knowledge transfer between different parties. And there is a lack of research to look into interpersonal communication within a living lab network. According to Huang et al., (2016), the personal ties between boundary-spanning personnel positively affected conflict resolution and cooperation amplification, especially the ties between people who work closely. This study shed light on the significance of human interaction within a living lab context. And this study inspired this thesis to investigate the learning process within a living lab on an individual level.

On an individual level, the complexity of actors may complicate the operation of living labs. Particularly, when stakeholders bring heterogeneous resources and knowledge into collaborative innovation activities, there may emerge a conflict of ideas between stakeholders and between the context and stakeholders (Leminen & Westerlund, 2012). Meanwhile, the mechanisms of boundary-spanning activities between actors involved in the learning process are rarely explored in the current study on living labs.

1.3 Research orientation

1.3.1 Aim and approach of the research

Thus, this thesis aimed to provide insights and a concrete communication tool regarding the individual learning process in a living lab context through a case study. There were two successive phases within the timeframe of this thesis. The first phase was to investigate both theoretical and practical sides of the mutual learning process among university living lab participants with diverse expertise in the case of Living Lab Medical Delta Instruments (LL Instruments). From a science communication perspective, social learning theories, especially the theory of community of practice, might provide a theoretical perspective on the learning process in boundary-spanning activities. Community of practice is a group of people who share a concern or a passion for something they do and engage in a process of collective learning (Wenger, 1999). Theories of social learning might provide a human-based perspective to frame the challenges emerging in the activities of living labs, and instructive insights to facilitate actors optimally experience and benefit from the learning process of living labs. After investigating the mechanisms and obstacles emerging in the boundary-spanning activities, the second phase of this thesis aimed to develop a tool that combines theoretical and practical insights to facilitate the learning process in the academic living lab LL Instruments.

The general methodology of this thesis applied the so-called double diamond approach, which was a method for design-based research developed by the Design Council (2004). There were two consecutive diverging and converging phases, with the shape of a double diamond. The first phase was explorative, which included a literature study on mutual learning theories and interviews of participants of LL Instruments. In this phase, the facilitators and barriers that actors experienced in the mutual learning process of the living lab were explored and identified. And these facilitators and barriers led to a problem statement to the realisation of an optimal learning process. Then in the second phase, based on the problem statement, several intervention scenarios were generated from a co-design session and then these scenarios were filtered or integrated into a final solution. The double diamond and all the research steps and corresponding deliverables of this research were depicted in Figure 1.1. More detailed descriptions of the methods used in this thesis could be found in chapter 02 Methods.

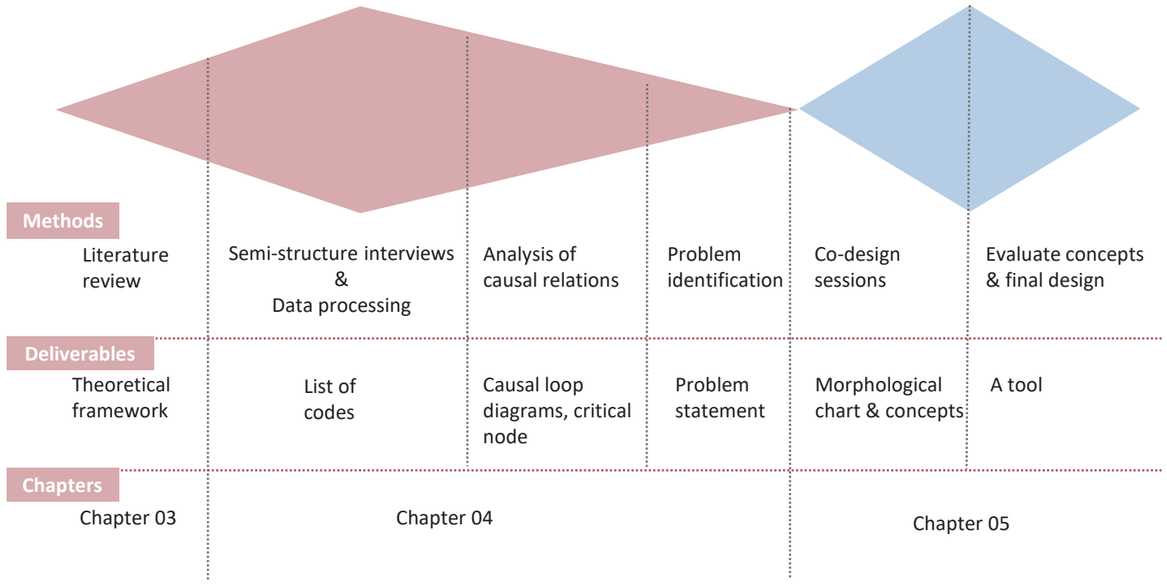

Figure 1.1 Illustration of the general research methodology.

1.3.2 Context of LL Instruments

The case of this research is Living Lab Medical Delta Instruments (LL Instruments). LL Instruments was initiated by Medical Delta, a Dutch collaboration organisation aiming to accelerate the development of innovative technological solutions that fit in the market. In order to develop innovative ideas for medical instruments further with one common theme "Circular & Sustainable Surgery", LL Instruments brings the technical and clinical researchers and medical devices companies into contact with each other to develop and high-quality prototype series intended for pilots in patients. In LL Instruments, TU Delft plays a leading role in collaboration with hospitals, and LL Instruments is currently coordinated by an assistant professor at the Department of Biomechanical Engineering.

At the beginning of this thesis, LL Instruments had several collaborative projects with medical devices companies and medical staff, such as surgeons. Surgeons are also the users of the medical devices that LL Instruments aims to develop. These collaborative projects became the rudiment of a living lab consortium.

In March 2020, inspired by the successful collaboration with partners from medical instrument companies in facing the challenges caused by scarce medical resources, LL Instruments was ambitious to upscale the collaboration from a project level to a living lab consortium, in which a strong partnership will be established. The vision of this living lab is to become an innovation incubator that boosts both scientific research and both marketable products, by bringing together networks between science, government and government agencies, hospitals and the medical industry. Moreover, in this innovation incubator, innovative ideas can be tested relatively quickly in healthcare practice. In close collaboration with medical specialists, representatives of the medical industry and researchers, research programmes can grow and realise better technological solutions for sustainable healthcare. In this current stage, the LL Instruments already have a group of interested and motivated partners in the living lab consortium, while the current question is how to realise "real collaboration" with all the various partners, as mentioned in the initial, explorative conversations with lab coordinator.

> *"So, the problems are not that there are no partners, (the problems are either not) that there is no interest, but (the problem) it is the distraction. So how can we create a living lab that allows real collaboration between all kinds of different partners and allows it to be a little bit more commercial than an academic university is without all those conflicts of interest." (Lab coordinator)*

1.3.3 Research question and structure of the report

In this research, the author looked into the current interaction and partnerships between individuals, to study their learning process and their perception of "a real collaboration". Through this process, problems that may lie in the interaction within this network could be identified from a social learning perspective. Later, the results of this research would be translated into a practical communication tool to facilitate the learning process in this context.

Here emerged a question on how to operate this living lab network optimally where actors are motivated to join in while the conflicts of interests are mitigating. This question became the research question of this thesis, which was formulated as follow:

> *How can actors of LL Instruments optimally benefit from mutual learning in a living lab network on an individual level, according to the social learning theory on communities of practice?*

The main research question has the following sub-questions:

1. According to literature, what are the influential factors of engaging in a living lab network on an individual level?
2. What is the ideal collaboration, according to people who engage in the collaboration of LL Instruments?
3. What are the most important elements of an optimal mutual learning process within LL Instruments based on both theoretical and practical perspectives?
4. What are the scenarios of solutions to support professionals to implement the final solution to achieve optimal mutual learning conditions?

This report will explore the first sub-question in the theoretical framework generated from a literature study. It can be found in Chapter 03 Theoretical Framework. The second sub-question concerns the practice of LL Instruments, and it will be investigated by interviewing and accompanying data analysis. The answer to the second sub-question can be found in Chapter 04 Results. The third sub-question takes a look at the combination of theoretical and practical perspectives, and it will be elaborated in the problem discussion section at the end of Chapter 04. The last sub research question will be discussed also in Chapter 05 Design, in the section of co-design and concepts.

The main research question of this thesis will be elaborated in Chapter 05 Design, 5.3 Final design.

02 Methods

In this chapter, the methods used for each of research steps will be elaborated and justified step by step in chronological order. The first section explains the research methods in the discovery phase, and the second section explains those methods applied in the design phase.

2.1 The first phase: explore the problem

In the first explorative phase, the research addresses sub-research questions 1 and 2. There were two analysis steps in the first phase to obtain a broad overview of influential factors of participating in a living lab from theoretical and practical perspectives. The first analysis of literature was used as input for the interviews and the second analysis of interviews aimed to identify critical nodes in the interaction within a living lab network. The result of this phase was the analysis of critical nodes of causal loop diagrams. The Figure 2.1 below shows the methods used for the first phase of this thesis.

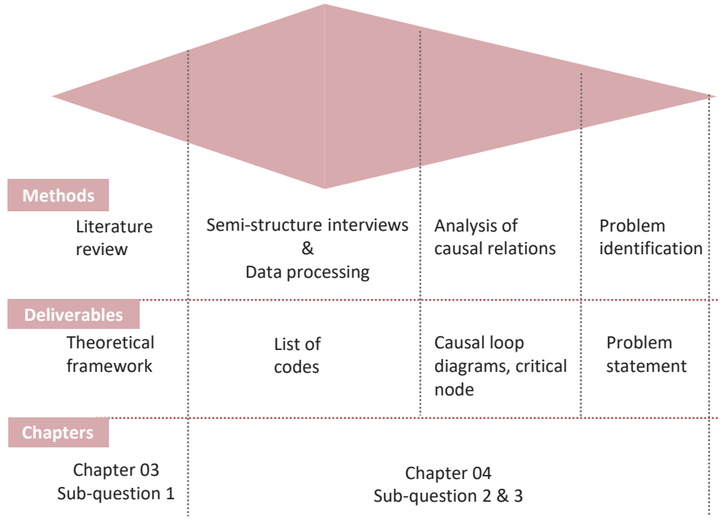

Figure 2.1 Research methods and report structure of the explorative phase.

2.1.1 Literature search and theoretical framework

This research applied deductive reasoning, and it aimed to explore the application of the learning perspectives of the theory of COP in the context of the collaborative innovation process, especially in the design and research line of medical device. Thus, it was necessary to set up a theoretical framework before exploring the practice and use it as a guideline of the case study.

The generation of the theoretical framework was guided by the first sub research question:

> *According to literature, what are the influential factors of engaging in a living lab network on an individual level?*

To answer this research question, first of all, the author tried to characterise the concept of living labs in the innovation process from existing literature. To realise this objective, a systematic literature review was the most relevant methods as it was a transparent and replicable way of structuring the literature research. Then, the characteristics of Living Labs are compared to an updated version of the theory of COP, learning in a landscape of practice (Wenger-trayner & Hutchinson, 2014). This stage applied a narrative manner.

The end goal of these two literature studies was to connect these two components into a theoretical framework. And the framework provides a scope for the semi-structured interviews.

Systematic literature review

The first wave of literature research is a systematic literature review in Scopus. The systematic literature review provided an exhaustive understanding of whether the application of Living Labs has particular benefits. With an explicit procedure, a systematic literature review was less prone to the biases of researchers. The methods introduced by Bryman (2015) were followed in this research. The search term was “living lab” (including “living labs” and “living laboratories” as well), which appears in titles, abstracts, keywords and full texts of papers. And within the results, the terms “innovation” was added. The results showed 203 articles or reviews after this process. Following criteria were applied in the selection.

1. Only articles and reviews with open access and published in English.
2. Articles concerning urban living labs were excluded because the focus of this research is academic living labs, in which the way of involving users was quite different from the involvement of citizens. For this reason, articles on urban living labs didn’t provide many references to the academic living labs. Thus, the keywords of “public” and “cities” were excluded.
3. Only articles and reviews that were published after 2010.
4. Articles concerning healthcare and Europe had the highest priority.

In the end, 21 peer-reviewed articles concerning living lab were selected as the starting point of literature study, based on the titles and abstracts.

Narrative literature review

The second wave of literature research was narrowed down to the concept of boundary-spanning activities and mutual learning process. The articles concerning these two concepts came from two sources. One source was through keyword research in Scopus, with the keyword “boundary-spanning” and “mutual learning”. The other source was the cited article from previously read papers with the topic on boundary spanning activities or learning. As a result, there were 20 papers selected for the topic of boundary spanning activities and 6 papers for the topic of learning.

The book Learning in Landscapes of Practice: Boundaries, identity, and knowledgeability in practice-based learning by Wenger-trayner and Hutchinson (2014) played an important role in constructing the theoretical framework of this research. In this book on the theory of COP, the process of developing identity in the mutual learning process was elaborated and discussed. In order to supplement the understanding of this process, 4 books and articles concerning identity, identification and professional identity were also included in the literature repository of this research. They were either recommended by supervisors or searched with the keyword “identity”, “identification” and “professional identity” in Google Scholar.

In the end, the theoretical framework of this research was constructed based on the literature mentioned above. Various literature was compared in order to identify how they complemented with each other. In the theoretical framework, relationships between various theories were indicated. The theoretical framework provided theoretical inputs for the case study.

2.1.2 Semi-structured interviews

The interaction and learning process of the case was investigated through semi-structured interviews on the stakeholders of LL Instruments to explore the answer of the second sub research question:

> *What is the ideal collaboration, according to people who engage in the collaboration of LL Instruments?*

The interview questions incorporated the structure of theoretical framework while being kept flexible and open. There were two purposes behind the semi-structured interviews. The first aim of the interviews was to obtain a comprehensive picture of LL Instruments by exploring individual motivations of participating in the living lab, respective expertise brought by each partner and their perception of ideal living lab partners and the interaction within the living lab. The second goal was to investigate the identification process in the living lab and compare the practice with identification literature. While exploring the questions concerning their professional identity, their identity of the living lab landscape, and the process of identification from the theory of COP, the author expected to find out what were essential elements and main obstacles in the process of building learning partnerships in practice.

Interviewees were active stakeholders of the LL Instruments, including surgeons, researchers, engineers from companies and innovative collaboration manager, respectively came from the key parties of LL Instruments partners. Their contacts were given by the lab coordinator after the first interview. The sample size was according to grounded theory, which means theta a study keeps going until the information saturation occurs as no new information is emerging in the data (Bryman, 2015). In the end, 6 interviewees participated in this research in total. Table 2.1 below shows the role and professional background of interviewees, and their names were concealed to respect their privacy.

Table 2.1 List of stakeholders interviewed during this research

Roles	Professional backgrounds	Indication in texts
Living Lab coordinator, assistant professor at department of Biomechanical engineering at TU Delft	Biomechanical Engineering (Sustainable Surgery)	Lab coordinator
PhD candidate at department of Biomechanical engineering at TU Delft	Busines Administration	PhD research
Innovation manager of Medical Delta	Material Science	Innovation manager
Engineer in R&D of an enabling technology company	Mechanical engineering (laparoscopic surgery)	ETC Engineer
Engineer in new product development in a customer company	Biomedical engineering (hip implants and instrumentation)	CC Engineer
General Surgeon in a community hospital	Medicine (endoscopic hernia surgery and paediatric surgery)	Surgeon

The method of data collection employed in this qualitative research was semi-structured interviewing. Compared with the structured interviewing in quantitative research, the interviews in qualitative research have an emphasis on greater generality of research ideas and interviewees' perspectives (Bryman, 2015). In order to answer the second sub-question formulated above, interviews were guided by an inventory of issues (Appendix A). Nevertheless, in the course of semi-structured interviews, the interviewer was supposed to be highly alert to what was being said to cast new questions that follow up interviewees' replies. As a result, interviews in this research had a conversational style and tended to be flexible as the interviewees would take the interview to the direction in which they addressed. In the interviews, sometimes the author also shared her understanding to a certain subject in order to create an interactive environment in the interview, where interviewees were encouraged to talk more. This also helped the interviewees better interpret the questions. But this behaviour had the suspicions of leading influencing interviewees. Thus, the transcripts should be sent back to interviewees for reviewing.

2.1.3 Data processing

All the interviews in this research were conducted and recorded via Zoom under the circumstances of Covid-19. Later on, the interviews were transcribed with Otter.ai. Every written text ensured to reproduce exactly what the interviewee said, word for word. The parts of an interview that could not be heard properly on the recording were indicated in the transcript that there is a missing word or phrase by using [???]. The contents that would reveal the identity of interviewees were concealed by using [ ]. The data collection and analysis happened simultaneously. During the process of transcription, the key issues, similarities and differences between different respondents' accounts were identifies and coded. The transcripts of all the interviews can be found in Appendix B.

The framework used for analysing qualitative data in this research was grounded theory. Grounded theory is an inductive approach which attempts to derive theories from data analysis (Babbie, 2016). After all the interviews were transcribed, the data were broken down into components and given names, namely codes. In the process of analysing data, the procedure of constant comparison should always be kept in mind. In constant comparison, the phenomena being coded were constantly compared under a certain category, in which a theoretical elaboration of that category was formulated and refined continually (Bryman, 2015).

The coding practice and data analysis were performed in ATLAS.ti 8. There were three steps of the data analysis. The first step was the open coding phase, where concepts emerged and were grouped and turned into categories. In the open coding phase, firstly the selected quotes of interest were labelled with open codes, and the codes were named by the essential information of the quote. For example, the following quote was at first given the code name as "Good relationship with users results in not too risky research for companies".

> *"In our case, the user is most often a surgeon or sometims you know, one of the ER nurses, or like people who clean the instrument etc. sometims what they want is just not what the professors want to research. No. But in Tim's case, because he does have, like he has good relationship with these people. And he usually like already has that in mind. So he's doing things that are publications and it is new technology, it's cutting edge, but nothing like we would say like to risky."*

After all the transcriptions were firstly labelled, there were around 90 codes in total, and with abundant repetition. For example, almost all the interviewees mentioned that one of the motivations of the collaboration was to maximally utilise their resources, but in the first step, these quotes were given different codes. By the end of data analysis, all the quotes about utilising network or collaborating with various partners were categorised in the code "GM - 1: You need everybody to make successful projects".

Then was the second step of data analysis. During this process, some similar subjects entailed by several codes emerged, and these subjects became themes. The quote exemplified above was part of the answer to the interview question: What would be a meaningful partner to you? Thus, the code was categorised into the theme of the definition of good partner. And then, the name of code was changed to "Good partner - Good relationship with users results in too risky research for companies". In this step, all the codes were categorised in a certain theme and the way of naming followed the form of "theme – code". In order to develop distinctive categories, a code was preferred to be a member of only one theme.

Following was the third step of data analysis. In the same theme, there can be found some similarity and difference among the codes, which can be grouped into subgroup, and each subgroup is a code group. Take the theme of good partner as an example, all the codes in this theme revealed two types of information, either who allow viable results or who have sufficient willingness in the collaboration. Thus, these two types of information became the two code groups in the theme of good partner, "Good partner 1: who allow cutting-edge research to be viable in industry" and "Good partner 2: who have sufficient willingness to engage". During this step, the name of the exemplified code was change to "GP 1 – 2: Good relationship with users results in not too risky research for companies".

In the second and third step, while the codes were being grouped, all codes were reviewed several times in order to abstract the essential information from a few codes with similar meanings. Through this process, the codes were merged and integrated with an iterative process.

The reliability of the coding process was ensured by peer review by a fellow graduate, Anneke Schouten, who studied the management of living labs. The validity of the coding process was ensured during the co-design sessions with interviewees. In the co-design sessions, the codes and code networks (shown as causal loop diagrams) were presented and validated with interviewees. The results of interview analysis can be found in Chapter 04 Results, 4.1 Interviews.

2.1.4 Causal relations in practice and critical nodes

All the codes were placed in two code networks based on their themes. The causal relations between codes were explored and the codes were organised in a causal structure. The code networks became causal loop diagrams after the causal relations were established, from which the critical nodes would be identified. Then the critical nodes served as a tool to identify the communication and collaboration related problem in the case study. The results were shown in Chapter 04 Results, 4.2 Causal loop diagrams & 4.3 Critical nodes.

2.2 The second phase: design an intervention

In the design phase, the research addresses sub-research questions 3 and 4. The third sub research question was answered in 5.1 Problem statement. In this section, the problem underneath the interaction within LL Instruments was elaborated and viewed from a theoretical perspective. After identified the communication and collaboration related problem in the first phase of the research, the second phase

aimed to design an intervention to positively influence practice. In the interviews, special attention was given to the collaboration related problems, and interviewees mentioned their perspectives and expectation on the collaboration. Thus, how to integrate the thoughts of stakeholders into a useful tool for lab coordinator, was the goal of the design phase.

The design phase also included a divergent phase and a convergent phase. The divergent phase started from a design goal, which was formulated as one sentence. Then content-based design criteria related to the design goal were composed based on the prior interviews and literature. The practice-based design criteria were generated from the conversations with fellow students in Science Communication programme and prior interviews. The content-based design criteria were validated in the co-design session. Meanwhile, preferable forms of the intervention were explored with stakeholders from the case study and communication professionals. The latter composed divergent solutions to the problem. From the morphological chart, the scenario of intervention generated. The final scenario should be able to operationalise the design criteria into practice. The Figure 2.2 below shows the methods used for the second phase of this thesis.

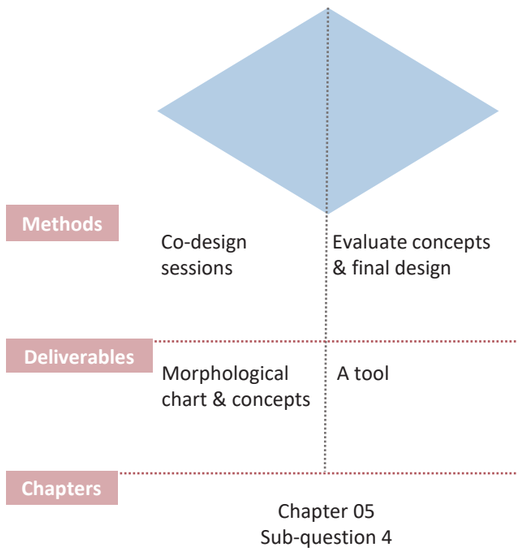

Figure 2.2 Research methods and report structure of the design phase.

2.2.1 Co-design session

In the co-design sessions, the participants from the semi-structured interviews were invited. Lab coordinator, a surgeon and an engineer from customer companies attended the sessions. Besides, a PhD candidate and a master student who were both familiar with designing a communication tool were invited and they both attended the co-design sessions. Because the measures of Dutch government against Covid-19, it was impossible to have participants together in a physical session. Thus, the co-design sessions of this research were conducted online via Zoom individually with different participants.

The purpose of the co-design session was to come up with an intervention facilitating knowledgeability in the group. The content-based design criteria were the starting point of this session. During the co-design session, the critical nodes and problem statement were presented. The problem statement was general ideas and was simplified in a concrete way to leave enough room for own interpretation. After an explanation of the problem statement, questions on potential scenario towards respective design criteria were discussed together. The complete protocol of the co-design session can be found in Appendix D

There were two phases in the co-design session. The first phase was the validation and interpretation of critical node and problem statement with stakeholders. In this phase, the author gave a presentation about the causal loop diagrams, critical nodes, problem statement generated from it. And then, the author gave a brief explanation of the three modes of identification serving as an introduction to the next co-design phase. In the second phase, the participants were first exposed to several scenarios generated from design criteria. Then they were required to speak out their actions to a scenario and the potential barriers or challenges. During the co-design session, notes were taken digitally in action forms. All the notes and filled action forms during the co-design sessions can be found in Appendix E. The contents of all the actions forms were gathered in a morphological chart. A morphological chart is a decision support tool with a schematic representation of the functions of the tool and proposed solutions to achieve those function.

2.2.2 Concept formation

In the convergent phase, by using the solutions from the morphological chart, three concepts were generated by the author of this research. These concepts have to be scored based on their ability in fulfilling the design criteria. And the method of assessing the concepts was discussed with the first supervisor, Steven Flipse. The concept that received the highest score was regarded as the best concept for further scrutinization. The highlights of the rest two concepts would be considered to be included in the final design as well if compatible.

The final design was adjusted based on the feedback from a fellow student from Science Communication master programme, Anneke Schouten, who was also studying Living labs for her master thesis, and the supervisor of this thesis, Caroline Wehrmann, whose main research field is professionalism and professional identity. Both of them gave constructive suggestions from a living lab perspective and professional identity perspective.

03 Theoretical framework

A theoretical framework was the result of the literature study. The generation of the theoretical framework was guided by the first sub research question: according to literature, what are the influential factors of engaging in a living lab network on an individual level?
The theoretical framework of this thesis aimed to view living lab theories with a perspective of the theory of Community of Practice (COP). In the end, the theoretical framework provided a scope for the semi-structured interviews.

3.1 Viewing Living Labs from a scope of COP

3.1.1 User as a partner in living labs

As mentioned in the Chapter 01 Introduction, living labs share the following characteristics despite differences in settings, subjects and sizes (van Geenhuizen & Guldemond, 2013):

- An early engagement of user group
- Experiment ideas in a real-life environment
- An open network which brings together stakeholders with the common desire of quicker and better innovation in the market.

These three points could be summarised as the philosophy of living labs, that people from various parties collaborate closely with users to innovate in a real-life environment provided by users. The philosophy of Living Labs manifests that there are various partners and users involved. The Living Lab partners and users are key components of Living Labs according to Bergvall-Kåreborn et al., (2009). The living lab partners and users bring their own specific knowledge and competence to the collective, and they actively help knowledge transfer across boundaries. By doing so, the collective learning and reflection occur in the living labs, which should contribute to both theory and practice. By allowing users to interact with the innovations that would influence their daily lives, the living lab methodology leverages real-life environment as an important element of the innovation process (Dell'Era & Landoni, 2014).

The user's role in the innovation process has evolved from passive users being observed or interviewed to actively participatory one, namely user as a partner. The early engagement of users in the design development process can create effective collective creativity (Sanders & Stappers, 2008). Meanwhile, in the healthcare sector which has a fragmentary nature, a strong interaction within a broader context is desirable because a weak interaction between industries and their system context may hamper the learning process and the promising innovations (Janssen & Moors, 2015; Schuurman, 2015). The partnership with users implicates a stronger connection between various parties, then how to establish a sustainable relationship or partnership between various actors in order to successfully exchange knowledge across boundaries draws the attention of scholars focussing on living labs.

3.1.2 External partners as learning partners in the living lab landscape

A team engages in boundary-spanning activities when it tries to establish relationships with external actors who are the parties that are outside the team, but within its embedding context (Marrone, 2010). There are two functions of boundary spanning activities in a living lab. The first one is to learn from external actors to improve the task performance of a team (Drach-Zahavy & Somech, 2010; Bresman, 2010). The second one is for impression management through which the team achieves legitimacy and support from external actors (Huang et al., 2016).

The boundary-spanning activities can be viewed in the scope of the COP theory, which focuses on the learning process within a community and learning in a landscape of communities of practice. The concept of landscape of practice has evolved from the original COP theory, the latter one focuses on exploring the boundary spanning activities among different communities of practice that constitute

a professional landscape (Wenger-trayner & Hutchinson, 2014). There are three characteristics of a community of practice, which are also suitable for a landscape of practice. These characteristics are listed below (Wenger, 2009):

- It has an identity defined by a shared interest;
- Members engage in collective activities;
- Members develop a shared repertoire of resources.

A living lab can be regarded as a landscape of practice, because the actors in a living lab usually share a broad common vision and engage in boundary-spanning activities in a living lab. The resources each actor brings to the living lab become a shared repertoire in this living lab landscape. The concept of COP is a method to build learning partnerships in the living lab landscape. In the perspective of COP, learning is a method to realise the two functions of boundary-spanning activities, which could be translated into improving own competence and increasing knowledgeability to the landscape. While the competence is used to describe the tangible knowledge that would be transferred and applied in a living lab landscape, the concept of knowledgeability manifests the abstract relationships that actors establish in the landscape, which allows them to have insights into the social expectation of the values of practices in the landscape. Knowledgeability indicates that people cannot be competent in all the expertise that was brought in the group, but all the participants can be knowledgeable about all the expertise of the others in the group and the relevance of this expertise to their own practice.

In general, living labs entail lots of boundary-spanning activities, in which actors from various disciplines are required to negotiate and collaborate with each other. Even though each actor has a different context, their drivers are similar, that a new configuration in which people and activities may bring new possibilities (Wenger-trayner & Hutchinson, 2014). The opportunity of reaping the benefits of boundary spanning activities lies in the tension between external actors, especially, in the process of becoming aware of these tensions and acting to overcome them (Benson, 1977). Thus, the boundaries are learning assets, and its translation in practice, for example, how to realise a productive encounter for negotiating and exploring a boundary and what happens in this process will be discussed in next section.

In summary, the combination of living labs theories and COP theory is the scope which views external partners including users as learning partners in the living lab landscape, and pays attention to the learning process within the landscape. Figure 3.1 below visualised this holistic scope as a combined view of living labs theories and COP theory.

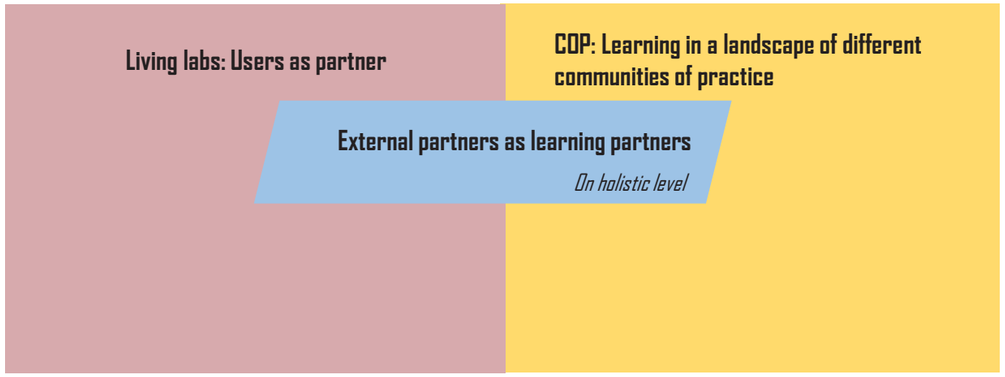

Figure 3.1 Viewing external partners as learning partners in the living lab landscape.

3.2 Developing identity in a living lab landscape

3.2.1 Professional identity

Professional development is concerning about the identity formation, and the identification process is entailed in personal learning trajectories (Wenger-trayner & Hutchinson, 2014). Identity is a set of characteristics that constitute a human, and people display a different combination of identities subset in a different context (Ruijters et al., 2015). Before we interact with others, we must first have an idea on our own basis, our values and our undeniable characteristics. The overlap of every actor's original identity is the foundation of initiate collaboration, and a highly developed personal professional identity facilitates collaboration by making clear what you can contribute to the collaboration. The ability to adjust and reshape identity according to the context and interaction with the environment also helps people cope with the dynamic workplace.

Identity is formed as a result of a trace of past interactions in the field of work, which may be in the form of conversations and practices. These external references, values and norms of a professional community are internalised and personally accepted (Monrouxe, 2010). Thus, professional identity is the commitment to perform competently and legitimately in the professional context. The formed identity of professional competence in turn becomes the basis of future interactions, and it is a dynamic existence that incorporates past and future into the meaning of present (Wenger, 1999).

According to Ruijters's definition of professional identity (Ruijters et al., 2015), in order to get a better picture of the identity, people must take a distance to view themselves and with many perspectives as possible. The professional identity includes two anchor points, their customers and their knowledge and experience. Namely, a professional is a service provider who has the competence to serve others.

There are a lot of definitions and descriptions of "a professional", and one of the aspects is that a professional knows what (s)he can't do, namely what (s)he needs to rely on others (Weggeman, 2015). Here, Weggeman referred to the concept of metacognition, in which metacognitive knowledge makes us aware of the possibilities and limitations of our own cognitive abilities.

3.2.2 Professional identity formed in living lab activities

Engaging in a living lab landscape can be a meaningful opportunity to develop their professional identity in a more dynamic environment with many perspectives. Through collaboration with different actors in the same field, professionals gain a better picture of both two anchor points mentioned above, and become a more competent service provider.

On the one hand, a professional has a better picture of their competence when engaging in a living lab landscape. While interacting with other actors in this living lab context, an actor will gain a better understanding of his or her competence and how can (s)he applies his or her expertise in this context. On the other hand, in this process, actors develop their profession as they have clearer a understanding of their possibility and limitations in the network (metacognition), as they know when help or input needed or when to leave tacks to others (Ruijters et al., 2015; Weggeman, 2015). This definition of profession accords with the concept of knowledgeability, which manifests the understanding of the interdependent relationships within a landscape. In other words, knowledgeability can be regarded as a

component of professional identity.

Here, the two anchor points of professional identity were translated into a COP language, that the identity of competence and the identity of knowledgeability.

3.2.3 Identification is an experience of knowledgeability

Practitioners engaging in the living lab landscapes are also living in the context of their own organisations, which have their own regimes of competence, commitments, values and perspectives. This is the professional frame of the professional identity, which is decisive on how people act or behave within the organisation. When people seek collaboration with external professionals, they also encounter and have to cope with the tension resulted from the differences in institutional frames (Ruijters et al., 2015). As a result, actors from different organisations may hold different perceptions of value, have conflicting objectives and material interests, which increase the difficulty of achieving alignments among different actors (Di Domenico et al., 2009; Powell et al., 2018). In the landscape of academic living labs, the institutional dimension of complexity reflects in the barriers in university-industry relations. Universities have an unfavourable profile of the invention, which includes a lack of outlook on mass production and strong technology risks because of the radicalness in research. These characteristics may cause a lack of interest of firms to engage. At the same time, the opportunistic behaviours of industries caused by unexpected business events may also disturb the collaboration between university researchers and firms (van Geenhuizen, 2013).

Thus, one opportunity to address these institutional differences is to incorporate the identity of knowledgeability obtained from the participation in the landscape in their original professional identity. In this way, the identification process within a living lab landscape can be regarded as an experience of obtaining knowledgeability.

Wenger-trayner & Hutchinson (2014) proposed three modes of identification that can be reflected in the trajectory through the landscape. First, engagement in practice, which is meaningful encounters where people in the landscape can negotiate their roles and collaborations. In the physical contact, actors directly experience the regimes of competence and the difference and similarity of other practices in the landscape (Wenger-trayner & Hutchinson, 2014). Second, imagination, which means the actors construct their own image of the landscape that helps them to interpret their roles and positions in it. And the last one is the alignment. Alignment with the context of the landscape is part of the identification as a professional. Through the two-way processes of coordination and negotiation, the actors influence and are influenced by the landscape they align to.

These three modes are interdependent with each other in the participation of living lab landscape. Engagement is the actual experience of the reality of the living lab landscape. And the reality is viewed through the lens of the beliefs and values of each actor, which generate the imagination and are translated into alignment in the future collaboration. Merely alignment is called linking activities which reflect the attempts to build relationships with external actors by conforming to and fit in the existing structure of that actor. And when an actor attempts to create a new relationship beyond the status quo by increasing understanding of the new context, building activities happen. These two categories of activities entail a sequence and a trade-off; that is, linking activities usually precedes building activities and linking to an actor means conforming to an existing relationship rather than building a new one (Harvey et al., 2014).

3.3 Theoretical framework and interview setup

Based on the c relations between theories of living labs, COP and professional identity as elaborated above, an overview of the theoretical framework is presented in Figure 3.2 below.

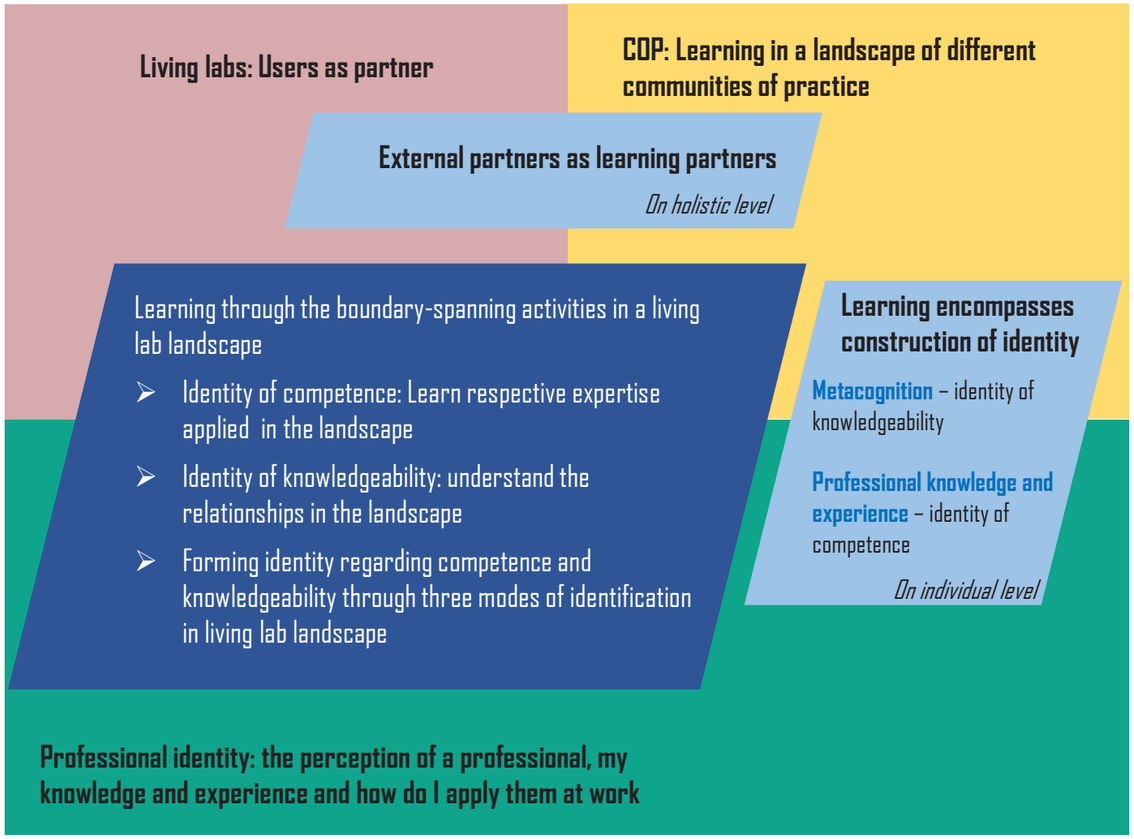

Figure 3.2 Theoretical framework of facilitating the learning process in a living lab landscape through identification.

The three coloured blocks represent the three main theories used in this thesis. On a holistic level, the link between theories of living lab and COP is to regard users and other external actors as learning partners in a living lab landscape. This has been elaborated in section 3.1.

The theory of professional identity provides an individual scope to view the activities in the living lab landscape as an identification process in which actors also improve their professionalisation. The combined scope between COP and theory of professional identity regards the learning process in a living lab landscape as a process of identification (light blue block in the right part of the figure). In the identification process, the concept of metacognition can be interpreted as the acquisition of knowledgeability to the landscape, while the professional knowledge and experience are summarised as the competence of each actor in the living lab landscape.

In this scope, learning in a living lab landscape is not merely to obtain knowledge beyond own specialisation, but also encompasses the dynamic construction of identities of both own competence and knowledgeability in the journey of the living lab landscape (Wenger-trayner & Hutchinson, 2014). Participating in the practices in a living lab landscape helps the actors constantly replay, experience and reflect their identities, both of their competence and knowledgeability. In short, the journey within and across practices shapes identities of actors. And in return, the process of identification helps actors positions themselves in the landscape because they obtain a clearer understanding of their competence and the relationships with other partners (Wenger-trayner & Hutchinson, 2014). Detailed elaboration has been given in previous section 3.2.

The dark blue block in the centre of the theoretical framework depicts the integrated results of all the theories that would guide the following research of this thesis. There are three main subjects to explore in the case study with interviewees, their identities of respective expertise, their knowledgeability to the living lab landscape and how do they experience the three modes of the identification process. The previous two points determine the ability of a group with different expertise to create meaningful results. And the last one was argued to facilitate the identification of competence and knowledgeability (Wenger-trayner & Hutchinson, 2014). These three bullet points are used as a guideline to design the questions of semi-structured interviews as shown in Table 3.1 below. Table 3.1 shows the clusters of interview questions based on the three bullet points of the theoretical framework and suggested codes based on the theories used in each question.

Table 3.1 Interview questions based on the theoretical framework

Clusters of questions	Interview questions	Suggested codes
Professional identity (identity of practice)	1. What's your daily responsibility in your own organisation?	Institutional frame
	2. What's goal of your organisation?	
	3. What expertise do you provide in this living lab collaboration?	Self-understanding as a service provider
Identity of knowledgeability	4. Why did you want to collaborate in this living lab?	Expectation
	5. What can you benefit from this collaboration?	
	6. How did you know the lab coordinator and started collaborating with him?	
	7. What would be a meaningful partnership according to you?	Common ground/Similarity
	8. What is the common ground between you and other actors? To what extent do you think you are address the same issue?	
Identification process	9. How do you work within the living lab right now? What's your interaction?	Engagement
	10. What do you think that you can achieve together in the living lab collaboration?	Imagination
	11. Have you experienced some differences during the living lab collaboration?	Alignment
	12. How do you deal with these differences?	

04 Results

In this chapter, the results of empirical research are presented. The results of interviews (4.1), the analysis of interviews (4.2 – 4.3), the discussion of the theoretical interpretation of the results (4.4) will be elaborated in order.

4.1 Interviews

At the end of the coding process, there were 30 codes generated from all the transcriptions of interviews. A detailed explanation of each code can be found in Appendix C. All the codes were divided into two main topics, motivation and perspectives on the operational level. The summary of codes, code groups and themes in this research can be found in Table 4.1 below.

Table 4.1 List of codes, code groups and themes in this research

Themes	Code groups	Codes
Motivation	General motivation	GM 1: You need everybody to make successful projects
		GM 2: Friendship
		GM 3: A call for sustainable medical devices brings people together
	Motivation of companies: efficiency and reliability	MoC 1: Collaborating with universities is more efficient than doing research ourselves
		MoC 2: Universities' wide range of capabilities makes their work more efficient
		MoC 3: We want publication to prove our reliability
	Motivation of researchers: increase competence	MoR 1: High-end projects with partners boosts your brand in university
	Motivation of surgeons: interests and publications	MoS 1: New perspective outside own discipline gives energy, ideas and fun
		MoS 2: Surgeons will get publication as return of their contribution
Good Partners	Good partner 1: who allow cutting-edge research to be viable in industry	GP 1 - 1: Good relationship with users results in not too risky research for companies
		GP 1 - 2: Companies want academic partners have certain market knowledge while focusing on academic research
	Good partner 2: who have sufficient willingness to engage	GP 2 - 1: Open door to share facilities
		GP 2 - 2: Spend time and effort to work on the same level to really make things happen

→ continued to the next page

Themes	Code groups	Codes
Expertise	Expertise of TU Delft researchers: technical competence	Er 1: Have a wide range of capabilities the technical expertise
		Er 2: Have the technical expertise to make things happen
	Expertise of company: with knowledge on fabrication and commercialisation	Ec 1: Make prototypes efficiently within fabrication limitations
		Ec 2: Make sure there's a viable product that can be commercialized in the ecosystem
	Expertise of surgeons: clinical experience	Es 1: Provide hands-on experience to make sure new technology is clinically effective
Perspective on project level	Pop 1: Matched interest	PoP 1: All partners have sufficient matched interests on sustainable surgery research line
	Pop 2: Separate interest	PoP 2: There should be a clear separation between research and commercial activities to avoid conflicts
	Pop 3: Need agreement beforehand	PoP 3 -1: Agreement on input and output should be defined well beforehand
		PoP 3 - 2: Input and output can be various form and need to be equal from all partners
	Pop 4: Interaction with surgeons	PoP 4: You need constant contact with surgeons and help them understand to make sure decisions in design are still viable
	Pop5: Knowledgeability	PoP 5 - 1: Actors should know what's important for each other and for together
		Pop 5 - 2: Difference in working ways are easily addressed
	Pop 6: Desirable results	PoP 6: Viable decision are made clinically, engineering and commercially
Perspective on a field lab consortium	LL consortium: Transferring knowledge from academia to industry	PoC 1: A living lab consortium: from a project to consortium
		PoC 2: The role of knowledge institute: research, education, valorisation
		PoC 3: Companies of enabling technologies are good at bring new innovations to market
		PoC 4: Customer companies: provide technological innovation to users

Motivation of the collaboration

Under the topic of motivation, there were two themes, seven code groups and 14 codes. The first theme was the motivation to join the collaboration. From the interviews, four types of motivation were found, respectively, general motivation, the motivation of companies, the motivation of researchers and the motivation of surgeons. These four types of motivation became four code groups under the theme of motivation.

For general motivation, there were three influencing factors. The first one was the mindset that people need to utilise the network and connection they already have to realise their ideas (GM 1). This was the main benefit of this collaborative network according to the PhD researcher in the group.

> *"(What this network benefits me) is the capacity of the partners…We need this cooperate for everybody. So, yeah, I think only together we can make this really successful projects, which might last years." (PhD researcher)*

Then, through the interviews, an interviewee mentioned that friendship also played a profound role in the collaboration, which was one of the reasons for him to join the collaboration. The friendship also reflected on the intense communication and a high degree of satisfaction of the collaboration. Friendship could serve as a facilitator of a favourable collaboration (GM 2). Furthermore, the last general motivation was influenced by the Covid-19 crisis at that time. During the pandemic period of Covid-19, the researches and innovation on sustainable medical devices increasingly drew attention. As a result, people became more interested in participating in the research line of sustainable surgery and this common interest brought people from different sections to work together (GM - 3).

For companies, the variety of their motivation can be summarised into two common objects, efficiency and reliability in the process of product development. First, collaborating with universities was more efficient than doing research themselves. Meanwhile, universities' wide range of capabilities made their work more effective. Through the collaboration with universities, engineers from companies can access to a wide range of capabilities to solve their problems (MoC 1; MoC 2). In the end, via collaboration with universities, companies had publications to prove the reliability of their product. Even though publications were not their main focus, it was also a bonus of the collaboration (MoC 3).

As for researchers, high-end projects with various partners could increase their professional competence (MoR 1). And for surgeons, they would obtain new perspectives to reflect on their daily work and publications (MoS 1; MoS 2).

The second theme in this network is the expertise of participants that could be brought into collaboration. Diverse and complementary expertise brought in by different partners was the precondition to create more values out of the collaboration. Strong technical competence was the expertise provided by academic researchers, which had two categories, one was the wide range of capability of various departments in universities (Er – 1), and the other one was the capability of making ideas happen. In the interviews, the technical expertise of researchers from TU Delft was acknowledged by engineers from companies (Er - 2).

> *"I think his idea is brilliant. I think they got the technical expertise to actually make it happen." (CC Engineer)*

Compared with academic researchers, engineers working in companies had more knowledge of fabrication and commercialisation. With this knowledge, they were able to provide a better estimate

of the feasibility of certain design (Ec – 1; Ec - 2). Another critical player in this collaboration were users, and in this case, were surgeons who use medical devices in their daily operations. Surgeons in the collaboration could provide hands-on experience to make sure new technology was clinically effective (Es - 1).

Perspectives on the operation

Under the topic of perspectives on the operation, there were three themes, nine code groups and 16 codes concerning the perspectives of interviewees on the operation of collaboration. The first theme was about the perspectives on a successful collaborative project. There were six code groups in this theme, each described one requirement or suggestion on the collaboration on a project level, including there should be matched interests but without conflicts of interest, the need of agreement before collaboration, the need of interaction with users, knowledgeability in the collaborative ecosystem and the definition of desirable results.

First of all, having sufficient matched interests in the research line of sustainable surgery was considered as the foundation of the collaboration by multiple interviewees (Pop 1). However, there should also be a clear separation between research and commercial activities to avoid conflicts (Pop 2). There was an intrinsic difference between the objectives of companies and academic institutions. The former pursued commercialisation and transferred the academic knowledge into industries, while the latter emphasised on scientific research and the generation of new knowledge (PoC 2; PoC 3; PoC 4). There was a blurry but certainly necessary line between the academic research and further development in industries in order to avoid conflicts of interest. And this led to the next code group: the need for an agreement beforehand. All the interviewees agreed that there should be a well-defined agreement at the start of the collaboration. In the agreement, input and output should be defined well, while all the participants should also keep the flexibility of input and output in mind (Pop 3 -2). The flexibility indicated that input and output can be various form but need to be equal from all partners (Pop 3 -1).

Previously, interviewees agreed that good relationship with users resulted in viable research for companies. In the practical operation with surgeons, how to optimally utilise clinical expertise in the decision-making of design was also an influential factor in the operational level. Interviewees mentioned during the interviews that in order to allow surgeons to better contribute to the decision-making, engineers needed to explain both the technical possibility and impossibility to help surgeons understand the situation. Meanwhile, constant contact with surgeons was also an effective manner to make sure decisions in design were still viable as mentioned by an engineer from a customer company (PoP 4).

> *"Yes, and it's really important because whole projects are quite long, you know, anywhere from 3 to 10 years, in that time, surgeons may change their mind, they use a requirement may change. So you have to make sure you're in constant contact to make sure that those decisions you've made are still viable, uh, still hold true." (CC Engineer)*

The address on knowledgeability was also already kept in mind by some interviewees. It was the question of why and when the actors should collaborate with whom on what. Interviewees acknowledged that they should obtain an understanding of each other's objectives and potential positions in the collaboration. Only when everyone expressed their own organisational expectations explicitly on this collaboration and understand each other's goals, they could later define a cooperative goal of the collaboration which allowed the realisation of each other's individual goal. From the cooperative goal, the project idea was generated.

Meanwhile, knowing the difference between partners and ourselves and actively in addressing the difference was also an important aspect of knowledgeability (PoP 5 - 1). During the interviews, interviewees indeed noticed some difference in the working ways between universities and companies. However, many interviewees regarded that this difference was easily addressed, and in their current collaboration, nothing stood out (PoP 5 - 2).

During the interviews, interviewees also elaborated their perspectives on desirable results of the collaboration. In the collaboration among researchers from technological universities, engineers from companies and surgeons as users, the optimal decision was made clinically, engineering and commercially. With inputs from these three parties, the decision would be more viable in the later commercialised process. In short, looking at all three elements led to a viable product in the end (PoP 6).

> *"…one of the big mistakes we've made, in hindsight is we leave the entire decision to the surgeons, the only one component of the decision. Decision is part-clinical, part-engineering, commercial. Look at all three aspects to make sure that you have a viable product." (CC Engineer)*

The second theme concerned the perspectives of upgrading the collaboration from project level into a consortium level. The consortium consisted of three main components, knowledge institutions, suppliers of enabling technology and customer companies (Figure 4.1).

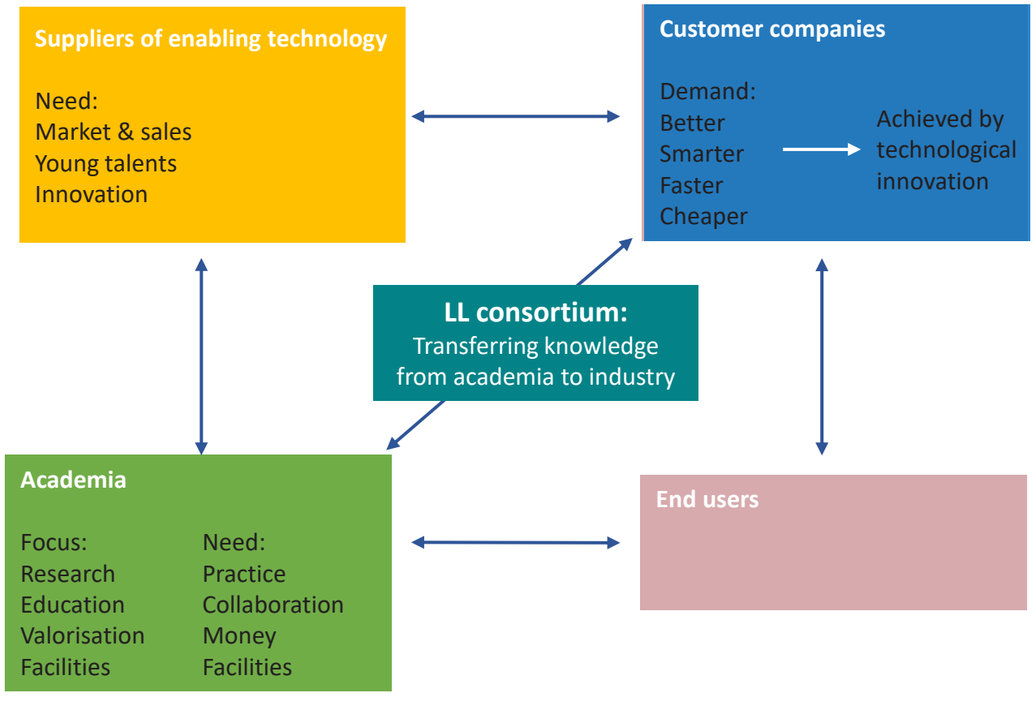

Figure 4.1 Illustration of the setting of a Living Lab consortium.

According to the lab coordinator, the consortium would be set up with academics and non-academics partners to find together a solution for problems of interest (PoC 1). Usually, the problems came from the clients, which were big medical customer companies. Usually, a consortium should start with a big cooperation project (PoC 1). The knowledge institutes were universities, or the university medical centres, which focus on research, education, valorisation as bringing knowledge to society. They had certain facilities to realise their function. In the biomedical or biomechanical field, if a researcher wanted to conduct good research, on the one hand, they need to know more about the daily practice of healthcare practitioners. Thus, they needed to collaborate with surgeons (PoC 2). On the other hand, doing good researches also needed money and facilities, which can be the input brought by various company partners (PoC 2). The suppliers of enabling technology were often companies, which have certain technology or solutions that can be applied in production. And these companies wanted to bring their knowledge from academic into the markets by offering solutions to other companies, which usually were bigger customer companies (PoC 3). Customer companies were usually bigger companies which directly develop new solutions or products to end-users. These companies were the clients in this consortium network. Customer companies worked with companies of enabling technology because the latter had really adapted the enabling technology to certain specific needs that customer companies had for their customers. Through collaboration with enabling technology companies and universities, the customer companies can directly adopt the knowledge and technology for their product development. Through this way, they could improve their product portfolio of interest in a better, smarter, cheaper and faster manner (PoC 4).

The last theme was the definition of good partners. During the interview, questions concerning the definition of meaningful partners were discussed. The recognition of each other as a good partner with whom interviewees would like to collaboration was also an important factor to initiate the collaboration. There were two types of good partners: who allowed cutting-edge research to be viable in industry and who had sufficient willingness to engage. Industrially viable researches were the result of a good relationship with surgeons, who were the users of medical devices design (GP 1 - 2). Knowledge of manufacturing also facilitated researchers in incorporating an industrial mindset in their design (GP 1 -1). Almost all the interviewees emphasised the importance of bringing time and effort to work synchronously and make things really happen. The willingness included sharing facilities, time and effort spending for good communication between collaboration (GP 2-1; GP 2-2).

4.2 Causal loop diagrams in the context of LL Instruments

All the codes were placed and linked in two causal networks based on the two main subjects of all the codes, motivations and perspectives of the operation. The codes of motivation network came from clusters of professional identity and knowledgeability (Table 3.1), except for the definitions of a good partner, which were considered fit better in the network of operational perspectives. The codes of the operation network came from the cluster of the identification process, which focused on the interaction in the collaboration.

In these two causal networks, the workflow in the system and causal relations were indicated. There were four relations in the causal loop diagrams. The relation of a facilitator was a blue one-way arrow, which indicated the facilitating relation between two nodes. The relation of a link was an orange two-way arrow. The two nodes which were connected by the link arrow reflected each other and conveyed similar information. The red and two-way arrow indicated the contradictory relation between two nodes. The purple arrows showed the interactive relation among the three main stakeholders of a living lab consortium.

Through this manner, the dynamic and interconnected context of practice was systematically articulated. The causal loop diagrams helped to identify where the exact problem may lie and what the possibilities were to address this problem. The division of these two code networks was not exclusive, some codes served as the point of conjunction between two code networks. Through these conjunctive points, the two causal loop diagrams could be integrated into one comprehensive causal loop diagram. In order to better explain the context of LL Instruments, the following paragraphs will elaborate on the two causal networks ordinally.

Motivation of participating in collaborative projects

The first causal network was regarding the motivation of participation and their own expertise which facilitated the realisation of their expectation. A consensus shared by almost all the partners was that “you need everybody to make successful projects” (GM 1). This consensus served as the central node of the network. Moreover, it was the conjunctive point to the other network of operational perspectives, through the code of “Pop 6: viable decisions are made clinically engineering and commercially”. At the moment of this research, the crisis in healthcare caused by the pandemic also rose more attention in the research line of sustainable surgery and incentivised people in this field to collaborate with each other to accelerate the innovation in this field (GM 3). These motivations brought people to this living lab consortium.

In order to realise the general expectation of successful projects, participants needed to bring in their own expertise in the projects. And their individual motivation would facilitate their devotion to the group. The role of surgeons was to provide hands-on experience in order to mould technical ideas back to the clinical reality (Es 1). There were two reasons for them to participate, one was the freshness and energy brought by the collaboration, and the other was a more practical benefit that they would get a place in publications (MoS 1; MoS 2). For researchers in TU Delft, continuously having high-end projects with various partners was an effective fashion to prove their academic competence (MoR 1). And in the collaboration, their wide range of technical expertise was the key to make brilliant ideas come true (Er 2).

Engineers from companies also had technical expertise, yet with a slightly different focus from researchers’. Engineers from companies had more knowledge on commercialisation and fabrication than academic staff, with which they could evaluate and contribute to the project with holistic and economically efficient perspectives (Ec 1; Ec 2). Engineers from companies made sure that the research would be viable in the future process of knowledge transfer. With regard to their motivation, companies would like to make use of the research done by universities, because it was cheaper than doing research themselves and with universities, they can have more focused researches on certain problems (MoC 1; MoC 2). Getting publications to prove their reliability was also a motivation for companies to seek collaboration with knowledge institutions, even though publication was not their main focus (MoC 3). Figure 4.2 below shows the causal relations in the code network of motivation.

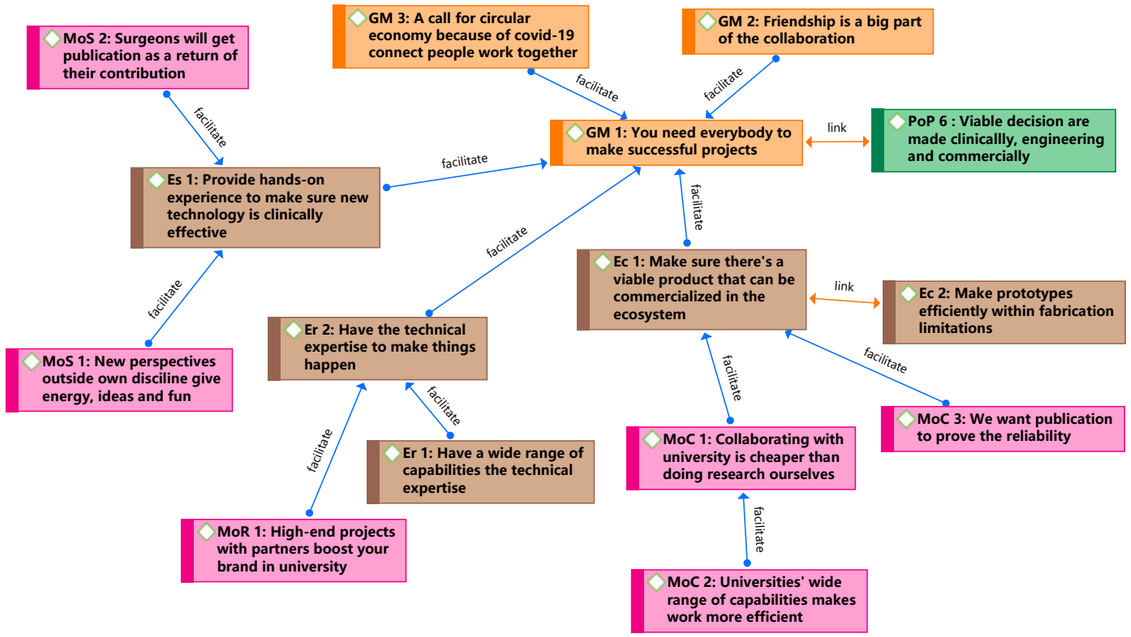

Figure 4.2 Causal loop diagram of the motivation of participating in collaborative projects.

Perspectives on the operation of projects and consortium

The second code network focused on the perspectives on the actual operation of collaboration. The network described and linked the practical requirement or suggestion of having a desirable collaboration with all the partners. The central idea was to set up a consortium with all the partners of a successful project. The idea of forming a consortium facilitated the general motivation of involving different partners (GM 1). The consortium applied the idea of a living lab consortium, where knowledge institutes, companies supplying enabling technology and large customer companies work together to bring new technology to the society through continuous projects. The consortium would be an autonomous entity and an incubator of new technical ideas. Through the interaction between these three components of the consortium, new ideas became a reality.

A successful project was the precondition of forming a consortium (PoC 1). According to the interviews, in such projects, viable decisions were made together by three elements, clinical practice, engineering expertise and commercialisation. Viable results of the collaboration reflected the central node of the previous network, that you need everyone to make successful projects (PoP 6; GM 1). On the one hand, in order to obtain the desired results, engineers and researchers needed to keep a good relationship with surgeons, who were users of medical devices. Involving users in the early phase of the research and design led to less risky results for companies to commercialise the innovation (GP 1 - 1). Constant contact with surgeons and helping them to understand the situation facilitated this objective (PoP 4). The latter manner could be expanded to the concept of knowledgeability, that actors should know what is important for each other and for together (PoP 5 - 1). Only in this way could all the participants contribute constructively to the desirable results. On the other hand, every participant needed to spend time and effort to work on the same level to achieve the desired results (GP 2 - 2). With the willingness to spend time and effort, differences were addressed and knowledgeability were increased.

To the right side of the causal loop diagram, the balance between common interests and conflict of interest were displayed. Sufficient joint interest was the starting point of the collaboration, yet there should be a clear separation of interest, which in this case, was between research and commercial activities (PoP 1; PoP 2). There was an intrinsic difference on the mission between companies and universities, however, during the actual collaboration on certain projects, the boundary was blurry, as the quote below showed.

> *"It's blurry because you don't want the professors to do market research or, or like something like that. But you also want them to a little bit, you know, think about it." (ETC Engineer)*

Thus, an agreement was necessary to discuss and be accepted by all the participants at the beginning (PoP 3 - 1). In the agreement, the input and output be defined well and agreed. What's more, all the participants should also realise that the input and output can be in various forms, including time, money, people, facilities and so on (PoP 3 - 2). An agreement made sure there was not overlapping interest in the collaboration and facilitated the achievement of desirable results (PoP 6). Figure 4.3 below shows the causal relations in the code network of operation.

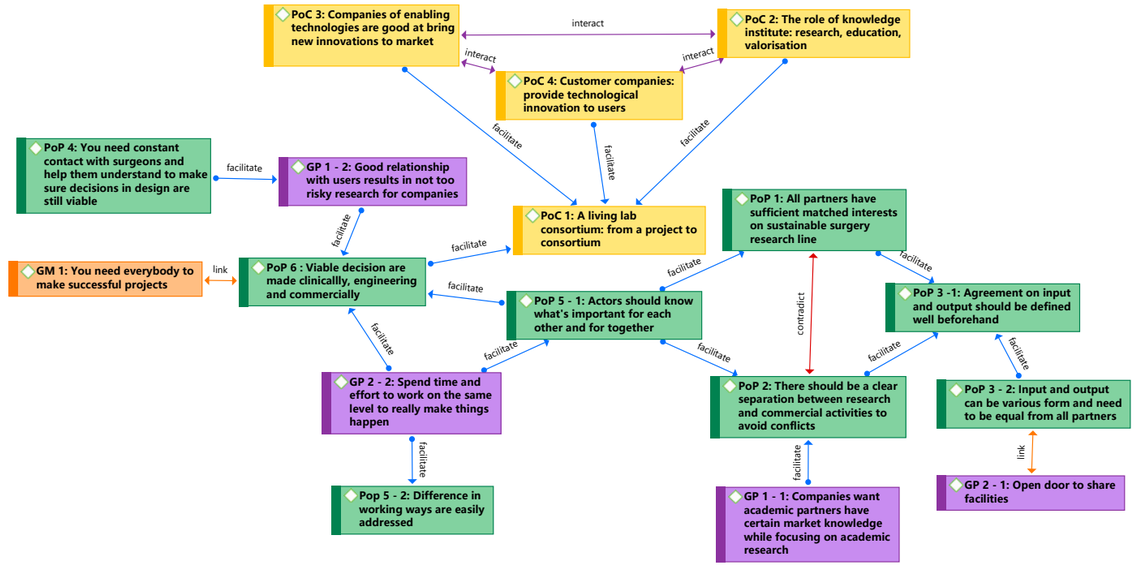

Figure 4.3 Causal loop diagram of the perspectives on the operation of projects and consortium.

4.3 Critical nodes

Derived from the overview of the case that was shown in the above sections, the critical nodes were defined as the joint point of two causal loop diagrams. They were the conjugated nodes between the diagrams of motivation and operation as shown below in Figure 4.4.

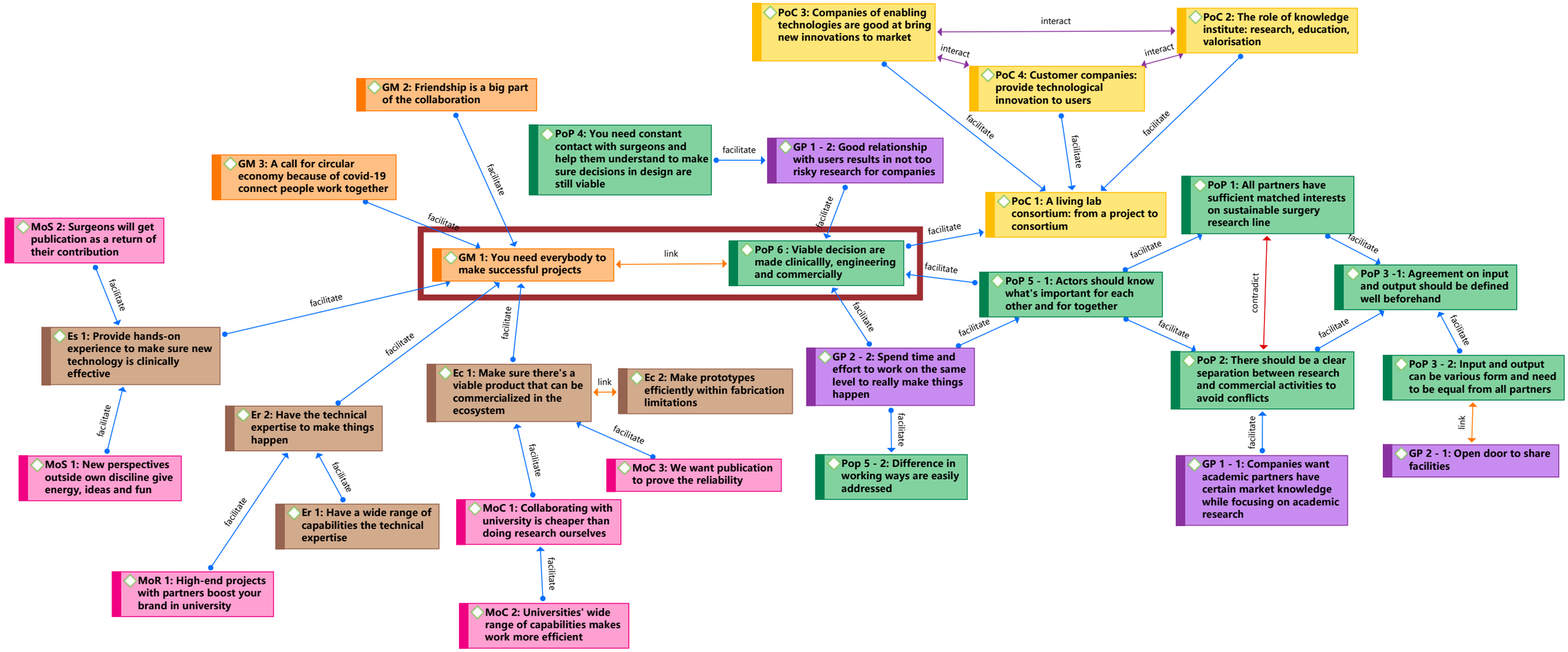

Figure 4.4 The critical nodes indicated in the centre of the combined causal loop diagram.

To explain this, first, we needed to go back to the first interview with the lab coordinator, in which he noticed that there was the distraction of partners and wanted to know how to create real collaboration among all kinds of different partners.

> *"So, the problems are not that there are no partners, (the problems are not) that there is no interest, but it is distraction that is now the main problem. So how can we create a living lab that allows real collaboration between all kinds of different partners and allows it to be a little bit more commercial than an academic university is. Without all those conflicts of interest." (Pop 2, Lab coordinator)*

This trouble was explored in the interviews, and then the causal relations around this problem were analysed in the two causal loop diagrams. Through this process, based on the practical context of this problem, the conjugated nodes were considered as the critical nodes of the combined causal loop diagram. This problem reflected respectively on the motivational level and operational level shown by the two causal loop diagrams.

On the motivational level, the subject was what intrigued partners with different competences to work together (Figure 4. 2). In the causal loop diagram of motivation, interviewees were aware of their respective unique expertise and their own motivation to participate. Especially, the expertise was the part of their professional identity and the set of competence that they would like to apply in the collaboration. Under the surface of their respective motivation was the consensus mentioned by all the partners that a successful project needed everybody's contribution (GM 1). Being aware of that they could not realise their ideal project solely, people were intrigued by utilising their existing partners and really collaborating with each other.

> *"The new part is really that we are doing good in like this kind of network. And yeah, we really try to utilise our resources like as best as possible." (ETC Engineer)*

However, moving from a common mindset to de facto smooth operation during a project could not be

realised by an armchair strategist. On the operational level, the problem was about what would be a practical requirement to realise real collaboration. The ultimate idea of causal loop diagram of operation was to set up a consortium with all the partners from a successful project (PoC 1). In a consortium, all the partners work together to facilitate the transfer of knowledge from academia to society through commercialisation (PoC 2; PoC 3; PoC 4). In the causal loop diagram of operation, the node PoP 6 was the practical counterpart of the motivation of involving everyone on a project level, that viable decisions in a project are made clinically, engineering and commercially. In the causal loop diagram of operation, all the perspectives on project operation facilitated the realisation of desired results, which was generated from the overlapping part of the feasibility scopes of all the expertise, respectively clinical, engineering and commercial aspect (Figure 4.3), that is, the decision should be feasible clinically, engineering and commercially. This node was also the answer to the question of what is real collaboration, according to interviewees. From the perspectives of practice, it was critical to make sure all the partners really contribute their expertise to the project from clinical, engineering and commercial aspects. By doing this, they tweaked the design together into the overlapping area in the feasibility scopes of all expertise brought to the group as shown in Figure 4.5. Having contributions from various participants was exactly the purpose of involving different partners in a project and collaborating. Without one of three components, the result would not be robust in the subsequent commercialisation in industry or really benefit society.

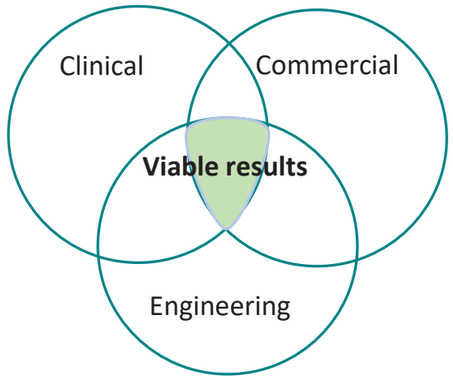

Figure 4.5 Viable results generated from the overlapping area of feasibility scopes of clinical, engineering and commercial expertise.

In short, the critical node isolated from the causal loop diagrams addressed the importance of actually involving different expertise in a project. And the practical translation of this "real collaboration" in the context of the living lab group was the results of the project were generated from the overlapping area of clinical, engineering and commercial aspects as shown in Figure 4.5. The viable results lie in the overlapping area of each feasibility scope of expertise.

4.4 Discuss the problem: The need of knowledgeability

After knowing what the ideal collaboration that the participants in this case study expected was, the thesis moved to the third sub research question regarding how to achieve the "ideal collaboration". This section will be guided by the third sub research question to discuss the key elements generated from the critical node from a combined perspective of theories and practice.

> *What are the most important elements of an optimal mutual learning process within LL Instruments based on both theoretical and practical perspectives?*

During the interviews, interviewees answered questions about their expectation and perspectives on the actual operation of the collaboration. All the interviewees also shared many practical experiences on the operational level (Code group: perspectives on project level). As shown in the causal loop diagram of operation, all the perspectives on project level facilitated the critical idea of involving clinical, engineering and commercial aspects in a project in either a direct or indirect way (Figure 4.3).

These perspectives from various participants could be interpreted by the theoretical framework, and be summarised as the need of knowledgeability. Knowledgeability indicted that people cannot be competent in all the expertise that was brought in the group, but all the participants can be knowledgeable about all the expertise of the others in the group and the relevance of this expertise to their own practice (Wenger-trayner & Hutchinson, 2014). In the problem diagram isolated from causal loop diagram, knowledgeability facilitated the realisation of the intersection of clinal, engineering and commercial aspects (PoP 6) and the identification of separate and joint interests (PoP 1; PoP 2) (Figure 4.6).

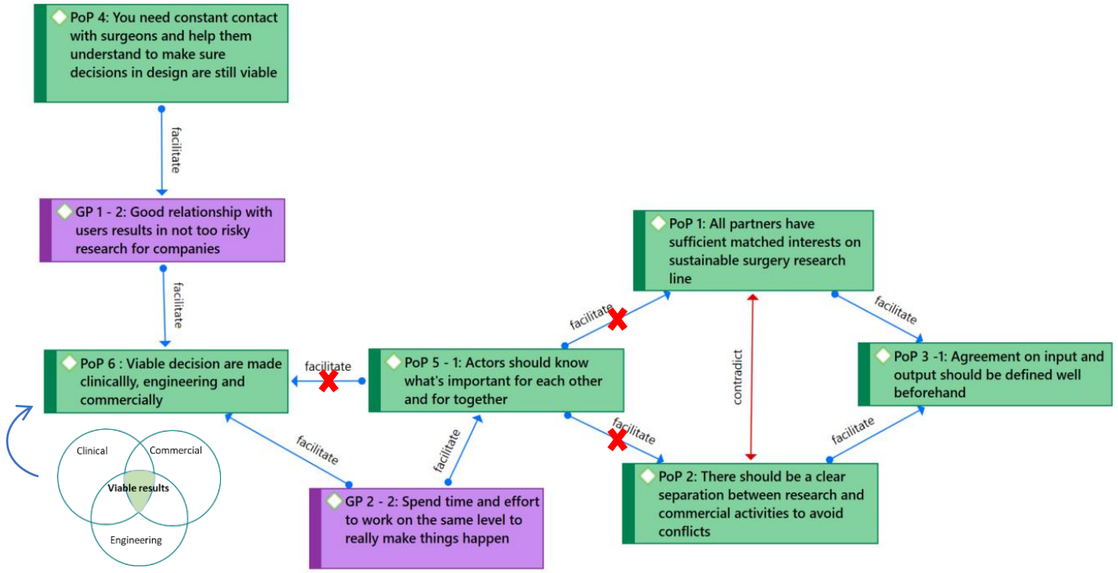

Figure 4.6 Problem diagram isolated from the causal loop diagram of operation

During the interview, participants also highlighted the importance of knowledgeability. Without knowledgeability, participants could not constructively contribute to the decision-making of viable design. For example, during the interaction with surgeons, engineers should explain the technical possibility and limitation to surgeons to allow them provided clinical suggestions in the scope of technical feasibility. In other words, engineers should help surgeons to be knowledgeable about the technical expertise of engineer in order to better involve clinical expertise in their design (PoP 5).

> *"So they experts in the clinical side of things definitely. But like you say they're not always aware of different manufacturing techniques, well, limitations of manufacturing techniques and you know, different materials that are available, etc. And one of the big mistakes we've made, in hindsight is we leave the entire decision to the surgeons, the only one component of the decision." (CC Engineer)*

Knowledgeability is also the first step of starting the collaboration, according to innovation manager. Only when all the partners understand each other they can define their common interests as a project and identify their separate interests to avoid conflicts as shown in Figure 4.6 (PoP 1; PoP 2).

"Yes, you have to take time for that. Because it's important for each of the partners to be aware of what's important for the other partner because then you understand each other and then you can understand well now, there is a project idea. And I can understand it's in interesting for the whole consortium as a whole, or is primarily interesting for me and only for small part, for the all the partner should be aware of that. I used to discuss about it. And if there's interest, there should be sufficient joint interest for working together." (Innovation manager)

More specifically, as articulated in the previous section, each participant, on the one hand, was aware of the expertise that they can bring to the group (Figure 4.2). However, on the other hand, they still need to understand others' expertise and understand others' objectives of the collaboration according to the concept of knowledgeability and the interviews (PoP 5-1).

"You want to work together, strongly together. We know what we want to achieve together. We know each other's positions, and we know together we are strong. Yeah. And that's what you need to define. And that's this process." (Innovation manager)

All in all, the main obstacle in realising the intersecting area of all the competence circles of clinical, engineering and commercial aspects lies in the insufficient knowledgeability of participants regarding the expertise of others. Having inputs from clinical, engineering and commercial aspects in a research project for viable results in the later commercialisation was the main purpose of setting up the real collaboration with various partners. In order to achieve viable results from the collaboration, all the expertise applied in the design should find solutions together within the scopes of other expertise brought to the group, as shown in Figure 4.5.

Thus, the illustration of viable results (Figure 4.5) could be theoretically interpreted as the result of intersecting identities of competence. The feasibility scope of each expertise can be regarded as each other's identity of competence on a personal level. It was the responsibility of each participant to tweak the design into the feasibility scope of their expertise. In this process, knowledgeability manifested the ability to help each other identify the overlap other's identity of competence. Before people start collaborating, there were three independent circles, and it was impossible to generate viable results that feasible according to all the expertise (Figure 4.7 A). However, knowledgeability can be learned during the interaction and the identification process within the group (Figure 4.7 B). With knowledgeability, which emerged during the interaction within the group or from previous professional experience, the competence circles came closer to each other and then participants were able to identify the common ground of their respective expertise. Knowledgeability manifests the intersecting identities of competence (Figure 4.7 C). Meanwhile, the identity of knowledgeability was also integrated to their own professional identities during the learning and identification process within the living lab landscape.

The previous literature study also revealed the significance of knowledgeability in practice in a multidisciplinary landscape. The next phase of this thesis was to integrate these thoughts from both practical and theoretical perspectives into a useful tool for a group of participants in a living lab context. This will be the main content of the following chapter: design a tool to increase the knowledgeability of participants. In other words, is to design a tool that facilitates the individual to help others become knowledgeable to their own expertise and simultaneously helps the group understand their own expertise.

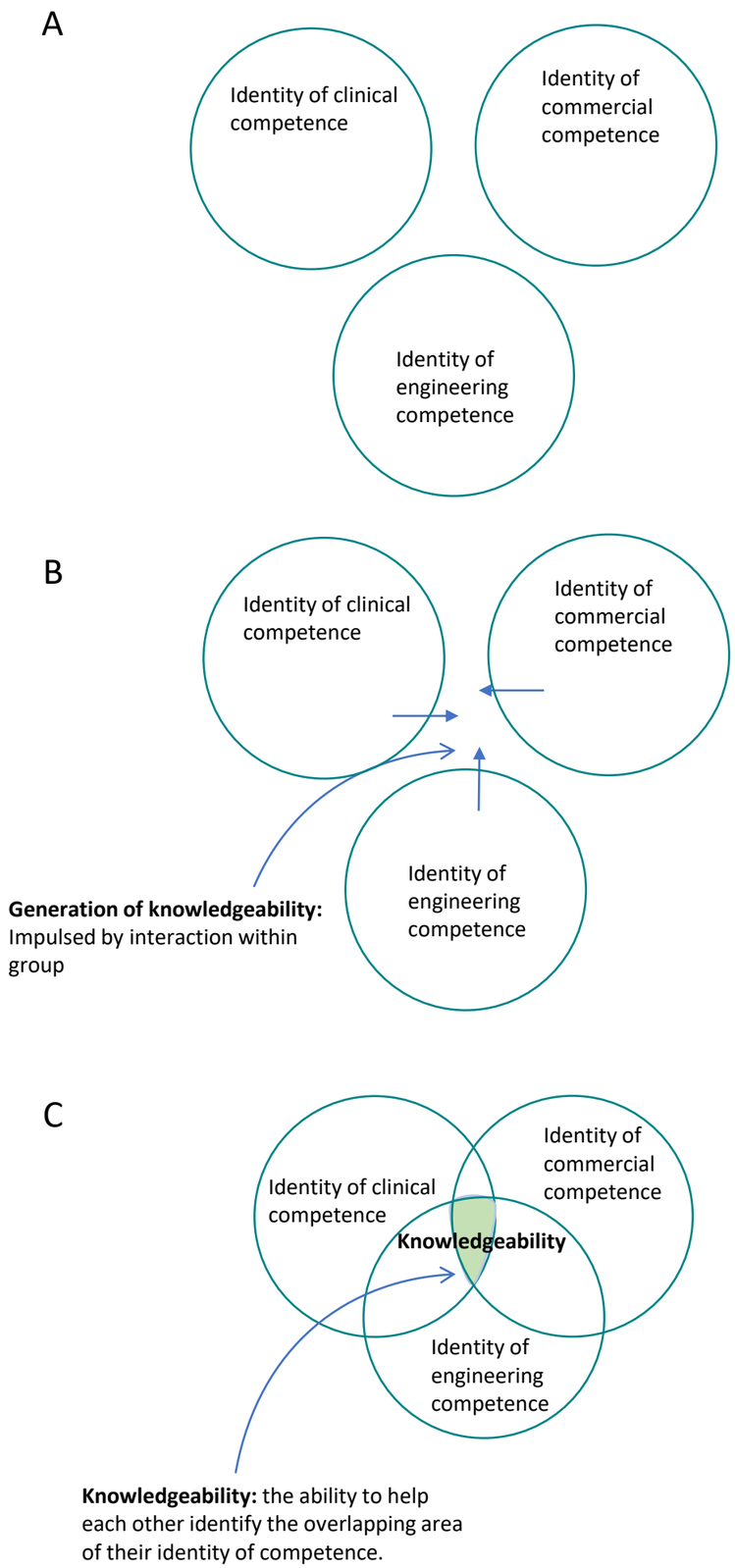

Figure 4.7 Illustration of the role of knowledgeability in identifying overlapping competence. A: no viable results when there was no knowledgeability; B: knowledgeability emerged during the interaction within the group; C: when people become knowledgeable to other competence, they could identify the overlapping area where viable results were emerging.

05 Design

In order to answer the sub-research question 4, this chapter focused on the generation of an intervention to realise the optimal results of projects through facilitating the acquisition of knowledgeability during the learning and identification process in a living lab landscape.

5.1 Design goal and design criteria

According to the critical nodes and problem discussed above, the design goal of this research was formulated as below:

> *To design a tool for the individuals in the group to help each other to acquire the knowledgeability of participants.*

With the knowledgeability, everyone in the group can contribute their own expertise in the ranges of each other's competence as already shown in Figure 4.7. The intervention to the problem generated from the combination of theoretical and practical insights regarding the identification process in a living lab landscape, which formed the content-based design criteria. From the perspective of the innovation manager, one indicator of knowledgeability is that people in a group needed to first know what's important for each other and for together, so that they could start collaborating (PoP 5-1). With a theoretical perspective, the acquisition of knowledgeability is accompanied by the dynamic construction of identity in the journey. The modes of identification are paths to make sense of the group and the position of everyone, especially the position of themselves in it (Wenger-trayner & Hutchinson, 2014). Thus, the three modes of identification formed the content-based structure of the intervention and became part of the design criteria of the tool.

5.1.1 Content-based design criteria

Engagement

The identification was accompanied by the interaction with other participants via three modes, engagement, imagination and alignment (Wenger-trayner & Hutchinson, 2014). First of all, the identification process included actual engagement in the collaboration. The engagement provided meaningful encounters where people in the landscape actually experience the differences in their perspectives and try to address them (Wenger-trayner & Hutchinson, 2014). Engagement was also a critical aspect mentioned frequently during the interviews. The interviews revealed that knowledgeability to the expertise of other participants generated from the interpersonal interaction. This was a two-way communication, i.e. during the interaction, people need to not only listen to the perspectives of others, but also need to help others understand their own perspectives and objectives (PoP 4, PoP 5 - 1).

> *"I tried to convince him [that the bright technical idea he thought for a long time is not gonna work in practice] but no always works. But sometimes at the end sometimes he's right…I try to guide them in the right direction, or to moulded the idea a little bit so that it becomes a nice, nice invention for the clinic." (Surgeon)*

The result of this two-way communication, where two participants worked together to tweak the idea to fit in both technical and clinical expertise, is "a very nice technical invention" according to the surgeon in the interview. And this could only be done through engagement as said by the lab coordinator (GP 2-2). Through active engagement, the differences and similarity were identified.

> *"There are a lot of people that claim that they bridge, they bridge the gap between surgeons and medical specialists and the industry and all the partners. But my experience is that it only can be done if you really start the project and you really be active in it and really make*

sure that things are being done." (Lab coordinator)

For example, engineers should constantly contact with surgeons and help them to understand the technical possibilities. This allowed surgeons to better contribute their clinical expertise in the frame of technical reality (PoP 4).

> *"Whenever you make a decision, really exploring things, you have to both show them what's possible, but also you have to show them what's not possible. […] So, we have to show them what's possible to make it realistic" (CC Engineer)*

Thus, the requirement of engagement generated the ***design criterion 1: the tool should initiate two-way conversations between participants in the group, where the ideas are guided into the intersecting area of all the ranges of the expertise.***

Imagination

The second mode is imagination, which means the participants constructed their own image of the landscape. The image of the landscape includes the consistently updated assumptions of the expertise of others and the relations to them (Wenger-trayner & Hutchinson, 2014). The interviewees did not explicitly address the mode of imagination, yet their interpretation on their contribution to the landscape and their positions revealed that all the interviewees actually had imagined their potential interaction with other participants in the landscape (Figure 4.2). Imagination played an important role in guiding participants during engagement. Imagination was the pre-assumption to the possible interaction and helped participants to prepare for and deal with the potential encounter of difference. The imagination smooths the collaboration between participants with different backgrounds as mentioned by the lab coordinator.

> *"Yeah people in [customer company] they know how surgeons think and what they are doing and…I am in between because…I…those people already…they know, yeah, they know what to deal with those people. That's no problem." (Lab coordinator)*

The central idea of involving clinical, engineering and commercial aspects in a project led each participant be aware of the interdependence of their respective expertise and objectives. And this consensus is the foundation of imagination, which helped participants to interpret their relevant roles and positions in the landscape. However, simple imagination may lead to harmful stereotype and become dissociative from reality. Thus, imagination is needed to reflect in engagement.

Based on the personal experience of the author, imagination could be split into two steps, make assumptions and validate assumptions. From this generated the ***design criterion 2: the tool should encourage participants to make relevant assumptions about the group and other participants,*** and ***design criterion 3: the tool helps people develop realistic expectations on the collaboration.***

Alignment

The last mode is alignment which is the premise of achieving effective practice in the collaboration. Alignment can be regarded as the common ground and based on which people move on the projects (Wenger-trayner & Hutchinson, 2014). From a theoretical perspective, the process of alignment in a boundary-spanning context includes two activities. The first one is linking activities, in which one

actor conform to and fit in the current structure and norms of another actor. While in the building activities, all parties try to establish a new relationship by interaction and a deeper understanding of the context (Harvey et al., 2014). The interviews showed that alignment was an important element for the collaboration, and there were two levels of alignment, one focused on the daily interactive decision-making in projects and the other one was the agreement of the collaboration. On the interactive level of the process of alignment, the similarity and difference were identified during the engagement and slightly difference was addressed (PoP 5 - 2). However, alignment simply with linking activities could be the source of frustration, especially when alignment between engineers and surgeons was the key to a viable technical invention (PoP 4). Alignment was a two-way process of coordinating perspectives, interpretation and contexts instead of a one-way process of submitting to one or other (Wenger-trayner & Hutchinson, 2014). Surgeons helped to mould the brilliant technical ideas back to the reality for the usefulness in the clinic, in return, engineers needed to guide the surgeons to contribute clinical perspectives within a range of technical possibility. Alignment was indispensable in the realisation of the three components in a viable decision (PoP 6), however, simply submitting to one actor was not the solution of alignment, as the quote showed.

> *"One of the big mistakes we've made, in hindsight is we leave the entire decision to the surgeons, the only one component of the decision." (CC Engineer)*

Thus, here generated the ***design criterion 4: the tool should encourage participants to communicate their perspectives based on their own expertise explicitly and create alignment from the results of coordination.***

On the institutional level, all the interviewees mentioned that it was critical to have an agreement before the start of projects during the interviews (PoP 3). An agreement is the legal and written form of alignment, where the negotiated and addressed similarity and difference were defined and served as the statute of the collaboration. Knowledgeability facilitated the identification of joint interests and conflicts of interest (Figure 5.5), thus, the design requirement from the institutional level of alignment could be achieved by increasing knowledgeability, through design criterion 1 to 4. With this respect, this intervention focused on daily interaction.

The three modes of identification are interdependent with each other. Engagement halters the imagination back to the reality, and allows people to actually experience the similarity and difference. Without imagination and alignment, people cannot deal with the difference they experience. And merely alignment is unthinking compliance, which cannot realise the equilibrium among clinical, engineering and commercial aspects that are needed for viable decisions.

5.1.2 Practice-based design criteria

The fifth design criterion was from the concern on the practicability of a communication tool, which was inspired by the fellow students of the master programme Science Communication. The ***design criterion 5 was formulated as follow: people need to be willing to use the tool.***

Because the identification is constantly developing, the tool needs to be used constantly to update the continuous development of the perceived expertise, roles in the group. This became the ***design criterion 6: people should use the tool for their daily communication.*** This design criterion is inspired by the interview with engineer from company, who emphasised that daily communication between people

who actually work together was vital.

> *"I think it's important to also see that, like, usually there's a PhD student working on a project and then on some engineer who works at the company, and they have to speak very often. So they are the ones who have to collaborate to make sure that that everything is being done at the same time. (…) It's important that the students and whoever in the company is working on the project have to be in direct communication." (ETC Engineer)*

5.2 Co-design an intervention

Using the content-based and practice-based design criteria, the goal of this phase was to develop an intervention for increasing the knowledgeability of the participants in the group. This was achieved by several online co-design sessions respectively with stakeholders from the case study and students studying Science Communication at TU Delft. In the co-design sessions, participants were exposed to all the design criteria and several scenarios which facilitate the interpretation of design criteria. Their actions to these scenarios and corresponding barriers and challenges of these actions were noted down in action forms. Their actions were regarded as solutions to the stated problem, and were gathered in a morphological chart.

From the morphological chart, three concepts of intervention generated. Then these three concepts were evaluated based on their capability in fulfilling the design criteria. The best concept will be further developed as the final product.

5.2.1 Revise design criteria during co-design sessions

There were three previous interviewees and two communication professionals participating in the co-design sessions of this thesis. They were respectively lab coordinator, surgeon, CC engineer, PhD candidate and graduating master student working on Living Lab and Science Communication. The protocol of co-design session can be found in Appendix D. There were two parts in each co-design session. The first part included a presentation about the interview results and design brief, including design goal and theoretical structure of design criteria. In this period, the interview results were validated with interviewees and communication professionals. Besides, the three modes of identification, which formed the content-based design criteria, were discussed with interviewees. During the discussion, the sequence between the three modes of identification was established as imagination first, then engagement and alignment was the last step. For a reason that imagination could provide a guideline for the engagement, in which alignment was achieved. And these three steps were recurring during the whole project and gradually enlarging intersecting area where the viable results emerged. Thus, the sequence of design criteria in the action forms was reorganised as shown in Table 5.1, which shows the template of an action form.

Table 5.1 Template of action forms

Design criteria	Scenario questions (with medical experts)	What's your action?	Barriers and challenge of the action
The tool should encourage people make relevant assumptions about the group and others	What kind of assumption/ you would make before collaboration? What kind of assumption is relevant to the collaboration?		
The tool should help people develop realistic expectations of the different roles and expertise that exist in the group	You made some assumptions, you would like to know to what extend your assumption deviate from reality. What do you expect on the roles and expertise of other partners? What would you do to steer your expectation to the reality?		
The tool should initiate two-way conversations between participants in the group to learn about the relevant expertise of other participants	You are reviewing a bright idea of your partner, and contribute the perspective of your expertise: this idea is not very feasible according to my field of expertise, and we need to adjust it a bit. But it is hard to convince my partner.		
The tool should support achieving alignment in the sweet spot of all the expertise, from engagement and imagination step	There is decision needs to be made, but how to make sure the decision lie in the sweet spot of all the expertise in the group? Do you know why your partner think differently from you? And how do you deal with it?		
People should be willing to use the tool	My supervisor/partner/colleague give me a communication tool which can help me better communicate in doing projects, what trait of the tool would intrigue me to try?		
The tool needs to be used constantly to allow update the continuous development of the perceived expertise and roles in the group	what trait of the tool would encourage me to use it constantly?		

In the second phase of the co-design session, each participant was required to describe what they would do when facing the scenario and aiming to achieve the design criterion. Their solutions were typed down on an action form via a shared screen on Zoom. And the barriers and challenges that might emerge along with the actions were noted down as well. All the filled in action forms can be found in Appendix E. All the co-design sessions of this research resulted in around seven solutions per design criterion which were gathered in the morphological chart (Figure 5.1). In the morphological chart, some solutions were mentioned twice, then these solutions were indicated by the darker green colour of the block.

Design criteria	Solutions from a practical aspect				Solutions from a communication aspect		Intuition of author
Encourage people to make relevant assumptions	Make assumptions on the resources that everyone can bring to the group	Make assumptions on partners' daily activities and the priority of their activities	Learn the background and experience of partners	Relevant assumptions have different emphasis at different stage of projects	Make assumption on the ability to fulfil their tasks. That depends on their capabilities and motivation	Let everyone write down their expectations and the expectation of their partners they perceived on the collaboration	Everyone list standard expectations on collaboration at the initial stage
Help people develop realistic expectations on the collaboration	Everyone should explain their own working process, with different emphasis on general procedure or topic-wise, which depends on the different stages of projects.	Provide a list of questions and answers about all the important expectations to create a standard common understanding before the first contact.	Get feedback to see if they understand, ask questions to explore where is the boundary of their expertise. Keep validating if you are on the same page.	Everyone should explain the boundaries of their expertise, which is based on their experience.	In a kick-off meeting, in which everyone establishes the end goal of the project and the roles that are required to fulfil that goal	After use the tool, do an exit poll to see to what extent the expectation meet reality, and note down how your expectation evolved through after the tool	Everyone should check if expectation on themselves is realistic
Initiate two-way conversations in the group to learn about each other's expertise	Constant communication should address changes immediately, and assess together the implications in everyone's field.	Dissection: Take a step back to the bare problem, differentiate the solution and problem	Have a blame-free environment, so people can express their understanding without being blamed. Mention very explicitly. Then have a discussion	Build trust on each other's expertise. Keep an open flexible mind for challenges.	Respect their expertise first, then explain the design process and then my conclusion based on that.	Go to a higher level: what's the collaboration about?	Together reframe the problem, when there is different opinions on solutions, encourage people to talk to people, use non-defensive communication
Support achieving alignment in the sweet spot of all the expertise	Reflecting to the end goals and relating within the surgical and technical context or procedure	Spend time to understand other's point of view, to see the workplace of each other.	Everyone evaluates the idea together based on their own expertise in a scale from 1-10, and give their opinions on improving the score	Put a weighting behind each aspect, and discuss and challenge the weighting based on priority, constraint on potential risks	Ask the priority per different perspective. And then, try to align these priorities.	Have trust and become transparent in their individual goal, information, and high strategic goal.	Alignment is built on understanding on each other's process
People should be willing to use the tool	Show the necessity of tool, why tracking identification is important for the collaboration	Describe a vision of this tool: what can you accomplish after using it, with example of good projects	A nice, friendly layout, intuitive	Very simple, introduce it at the early stage of the project. And let everyone agree the meaning of each steps in the circle.	The tool will fit my daily activities, my current way of working. The promise that the tool will make my work in LL more efficient.	Guide participants to use at the first time, then they can use themselves	Should be interactive, and encourage the interaction with people
People should use it constantly	During the projects, when milestones are reached, really to reflect on what is developed, and what it means for the project.	Integrate to the planning of the project, to see if every milestone is achieved and how development is going.	Time-efficient. it become the process. Easily integrated to your daily work	Invite all participants to comment on it	Remind them, the knowledge that the other stakeholders use it too.	Have reflection moment continuously, the tool shows their changes	Show their process of identification intuitively
Concepts	Concept I: Portal website			Concept II: Logbook		Concept III: Boundary-spanning serious game	

Figure 5.1 Morphological chart including the process of concepts generation, where only the concept that could best conduct the solutions to realise the design criteria would be indicated by colour dots in the solution blocks. The solution that could be fulfilled equally by all the concepts would be tagged by three colour dots.

5.2.2 Concept Formation

The action descriptions from the action forms were summarised as a one-sentence solution and placed on the morphological chart, which has three categories of the solutions, respectively from a practice perspective, from a communication perspective and the intuition of the author.

In order to come up with several concepts of intervention, tool or method, the solutions on the morphological chart could be combined. All the design criteria needed to be taken into account, as at least one solution of every design criterion had to be included in each concept. Three concepts were generated during this process as a result of connecting solutions. The three examples were a portal website (red dots, concept I), logbook (yellow dots, concept II) and boundary-spanning serious game (blue dots, concept III). During the concept generation, only the concept that could best conduct the solutions to realise the design criteria would be indicated by corresponding colour dots. The solution that could be fulfilled equally by all the concepts would be tagged by three colour dots (Figure 5.1).

The respective functions, users, advantages and pitfalls of these three concepts will be illustrated as follow.

Concept I: A portal website for external and internal communication

The lab coordinator suggested the concept of a portal website during the co-design session. A portal website could be helpful in creating a standard expectation for the initial meeting and help users be updated about the changes in the project. These turned out the two main functions of the portal website. One function was for external communication, where relevant expectations on the collaboration were listed and a standard common understanding was created before the first contact. The public part of the portal website served as a showcase of the consortium. The other function was for internal communication after people start actually working together. The exclusive part of the portal website was to enhance the efficient communication on each milestone of the projects and invite various input from all the expertise in the group. More detailed information about this concept is listed in Table 5.2 below.

Table 5.2 Functions, users, highlights and pitfalls of concept I: A portal website.

Functions	➢ Provide a list of standard expectations on the collaboration to create a common understanding for the first contact ➢ Provide a platform to talk about the decisions on the project and encourage people to explain their own perspectives to the group ➢ Constantly remind people to reflect to the end goals and relate to their own expertise
Users	➢ Owned by the lab coordinator, and the exclusive part is shared by relevant participants within a certain project
Highlights	➢ Both for external and internal communication ➢ Can be well integrated to the development of the project, and served as a central platform for collaboration ➢ The discussions on the website are recorded so that they can be easily checked
Pitfalls	➢ Highly depends on people's willingness to share their thoughts on webpage ➢ To what extent the internal website should be structured is a difficult question, as a result, people may be confused about what kind of milestones that they should put on the website and who should do that. Then no one would take the responsibility.

Concept II: A semi-structured logbook for daily communication

During interviews, a lot of stakeholders mentioned the importance of daily communication (GP 2-2). Behind this idea was the concept to write down the process of developing realistic expectations and the learning process of knowledgeability during the interaction. Keeping a diary about our performance is an effective way to encourage self-reflection. The author personally benefits from the self-reflection assignments during her master study. Meanwhile, a self-reflective diary approach has been proven to facilitate cross-cultural adaptation (Xu, 2018). Here generated the concept II, a semi-structured logbook. Incorporating the solutions such as asking questions to explore the boundaries of the expertise, noting down how expectations developed after actual engagement and having constant communication on changes, the tool emphasised the daily communication between people who actually work together closely. More detailed information about this concept is listed in Table 5.3 below.

Table 5.3 Functions, users, highlights and pitfalls of concept II: A semi-structured logbook.

Functions	➢ Guide users to conduct conversations incorporating the three steps of identification ➢ Record the learning process of knowledgeability during daily communication of the users for constantly checking on ➢ Encourage users to reflect on the development of knowledgeability after join the group
Users	➢ Every participant in a project owns one
Highlights	➢ High frequency of use conduces the development of a habit to use it ➢ People can use it individually and have high level of autonomy ➢ Can be well integrated to their daily work
Pitfalls	➢ A logbook might easily end up in a drawer to never be used ➢ People may use it alone and not share their thoughts on the logbook with each other

Concept III: Workshops of serious games that facilitates the boundary-spanning activities

As a prime example of serious storytelling, serious games allow the creation of knowledge and wisdom because the storytelling evokes cognitive emotion in its audience (Lugmayr et al., 2017). Some major characteristics of serious games include focusing on problem-solving and learning (Susi et al., 2007), thus, serious games could be a useful method to increase awareness and develop skills on the acquisition of knowledgeability during the interaction with various specialists. The workshops could give people an opportunity to validate their expectation and create a common understanding for the next step together. More detailed information of this concept is listed in Table 5.4 below.

Table 5.4 Functions, users, highlights and pitfalls of concept III: Workshops of serious games.

Functions	➢ Obtain realistic expectations on partners ➢ During the workshop, let people become familiar with the three modes of identification so that they can apply those in their daily work ➢ Increase the interaction and understanding between partners, and build interpersonal relationships during the workshop
Users	➢ All the participants of a project
Highlights	➢ The learning efficiency is high and intuitive thanks to the high level of interaction ➢ People can benefit from the interpersonal relationships built during the workshop ➢ It is enjoyable and structured
Pitfalls	➢ Need someone lead the workshop all the time ➢ Can't really fit in their daily work ➢ Can be hard to find a time for workshop with all the participants

5.2.3 Choosing concepts

The best concept was selected by evaluating all concepts on each design criterion. The weight of every design criterion was all the same. The priorities of the three steps of identification were already manifested by the number of design criteria generated from each step. The most important step was imagination, which was the first step of the three modes and was found being neglected during interviews. Because there were already two design criteria generated from imagination, these two criteria would be given the same weight as other criteria. In the morphological chart, every block weighed 1 point. Some solutions were mentioned twice, then these solutions weighed 2 points. These 2-point solutions were also indicated by the darker green colour of the block (Figure 5.1). As mentioned before, only the concept that could best conduct the solutions to realise the design criteria would be indicated by corresponding colour dots. The way of assessing the concepts focus on the inclusive aspect of the concept, which means the assessment calculates the final score of every concept regarding to their capability to fulfil all the design criteria. The results are depicted in Table 5.5

Table 5.5 Concepts scored on each design criterion. The final scores are the sum of scores every concept obtains based on their capability to fulfil each criterion.

	Concept I: website	Concept II: logbook	Concept III: serious game
Make assumption	5	3	4
Develop realistic expectations	1	2	1
Initiate conversation to learn	1	3	1
Achieve alignment	3	2	1
Willingness to use	4	6	3
Continuously use	4	4	1
Final score	18	20	11

As shown in the results, the best concept is concept II, A semi-structured logbook for daily communication. Actually, concept I and concept II received approximate scores during the assessment of concepts. However, concept II focused more on individual interaction and had a higher level of personalisation, which fit better to the research question of this thesis. Thus, concept II was chosen to become the basis of the final design. At the same time, the highlights of the other two concepts will be integrated into the final design if compatible. For example, the active interaction between users from concept III and a standard information of the collaboration form concept I.

5.3 Final design

5.3.1 Development of final tool

Because of both the current social-distance policy and the trend of digital transformation, the logbook would have a digital format, which preferably would be an application on PC or mobile phone. A digital logbook is also more flexible for changes so that people can personalise their logbook. There are three components in the design process of the logbook. The first part is the user manual of the tool, including the necessity of using the tool, the methods of application and a vision after using the tool. With the manual, the lab coordinator would take the responsibility of introducing the logbook to everyone in the projects. The second part is the logbook itself, which has instructions based on the three steps of identification to guide the conversations within the group. The users are guided by some inspiring questions to note down their learning process in the logbook and encourage them to reflect on the course of interaction. With the tips or inspiring questions on the sidebar of the logbook, users can learn some communicative solutions and add tips based on their own experience to share with the group. The last part is the interactive group page of the logbook. There are two functions of the group page, the first purpose is for everyone in the group to continuously track the development of the project. The other purpose aims to encourage the interaction within the group through the function of adding comments to the group page.

During the development of the final concept of the tool, the concept was presented discussed with a fellow student from Science Communication master programme, Anneke Schouten, who was studying

Living Lab management for her graduation thesis; the second supervisor of this thesis, Caroline Wehrmann, whose major research focuses on professionalisation and professional identity and the lab coordinator of the case study. They gave constructive suggestions from diverse perspectives for further finalising the concept, as listed below.

- The tool should have clear instruction on how to use and intuitive user interface. Users should have the chance to know the function of each button, even though not every user need instruction in detail. (Anneke)
- The tool should help people reflect on their identification process and become aware of that knowledgeability is becoming their part of professional identity when using this tool. By achieving this objective, the tool reflects on the theoretical framework. (Caroline)
- Because of the time limitation, it is not possible to have a real product of the tool. Thus, the concept of the tool should be intuitive to make a prototype and give clear recommendations for the next step. It would be helpful to use a storyboard to present the concept. (Lab coordinator)

These suggestions were incorporated in finalising the tool, which will be presented in the next section.

5.3.2 Final concept: Learning through my project

The final tool is called Learning through my project, which is a semi-structured digital logbook for daily communication. There are three parts in the tool as mentioned before. One is a general user manual in which the significance of using the tool is explained briefly. One is an exclusive part for individually using, which helps the user to structure the conversations strategically and remind them to pay attention to the potential boundaries between them and their partners. The individual part can also be used for daily communication since the tool assists the interdisciplinary conversations by providing communicative solutions on the individual page as well. Through this way, the tool is expected to improve the learning quality of conversations and inspire users to reflect the development of identity in this course. The last part is a shared platform for everyone in the group, where people can fill in their aligned statements together and constantly track their decisions on every milestone during the design process. The following paragraphs will introduce these three parts one by one.

User manual

The user manual aims to intrigue people to adopt the tool for their projects. In the manual, the necessities and benefits of using the tool is introduced briefly according to the morphological chart (Figure 5.1, “Show the necessity of tool, why tracking identification is important for the collaboration”). The manual will be the entry interface of the tool, with answers to the following questions:

- Why do you use it?
- When do you use it?
- How do you use it?

The manual of the tool is shown in Figure 5.2 below.

Figure 5.2 The manual of the tool

Individual logbook

The second part of the tool is the logbook itself. The logbook is semi-structured which gives three steps to guide the conversation, while the users control the subject and the flow of conversations. The first step is preparative imagination on the potential interaction. The main purpose of this step is for users to prepare for the possible encounter of difference. But it can also help users structure the conversation agenda when they write down the answers in the blank block next to the questions.

The second step is the actual engagement in the conversation and experience the difference and boundaries between expertise. The inspiring questions in the corresponding block serve as a guideline to stimulate learning from the perspectives of your partner while addressing the difference. While answering the question in the engagement block, users are also motivated to reflect the display of their professional identity during the boundary-spanning activities and learn from their partners’ perspectives.

The last step is to write down the alignment generated from the conversation, which can be simply the results of this conversation, but can also be the milestone agreed by everyone in the project. It is best to check the aligned statement with partners before put it on the collaborative group page.

In the individual page, there are some hidden explanations on the purpose and detailed method of use of every step. Users can click on the exclamation sign to expand the explanation. They help user to understand the design of the tool and how to utilise this tool for the first time better. The individual logbook of the tool with expanded explanations are presented respectively in Figure 5.3.

On the left top side of the individual page, there is an expandable block called Communicative Solutions, in which users can learn some solutions for their conversations for references and also add solutions to it based on their own experience. The solutions currently available came from the morphological chart generated during co-design sessions. The solutions provided by the Communicative Solutions all guide the users to better increase knowledgeability of themselves or their partners. There are three main categories of communicative solution at this moment. One is viewing the interaction with various partners as an opportunity to learn other perspectives. One is regarding how to explain own expertise to other partners. And the rest is to create a blame-free environment. The Communicative Solutions is for individual use as well because the self- supplement function where users can add solutions themselves. If the group shares the Communicative Solutions, then everyone in the group can add tips which may not be agreed by the rest of the group. This would lead to a messy Communicative Solutions, and by then no one would like to use this function. The communicative solutions with explanations of the buttons is shown in Figure 5.3 as well.

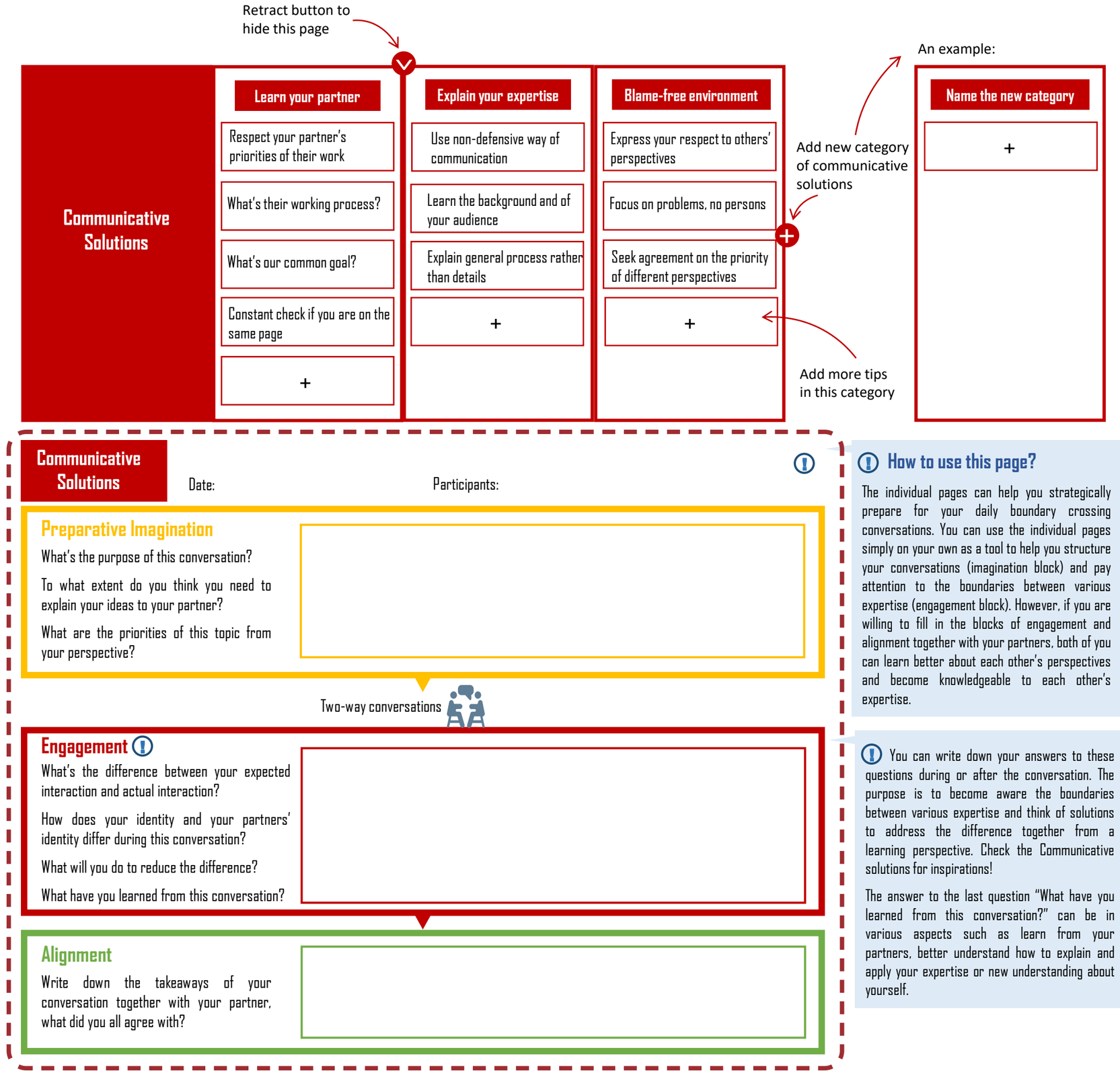

Figure 5.3 Individual logbook of the tool. In the middle is the original individual logbook (within the dashed frame); to the right of the logbook are the expanded explanations of this page; above the logbook is the expanded communicative solutions with explanation of the buttons and examples.

Group page

The interactive group page is a collective platform for the whole project group, where people can fill in their aligned statement of every milestone during the design process and check the new comments from which potential changes may occur. The interactive group page is for everyone in the group to continuously track and review the development of the project, and initiate conversations within the group through the function of adding comments to the group page. Furthermore, because this collective page lists the critical milestones of the design process, it is more convenient for the lab coordinator to explain the design process and workflow to the newcomers. The illustrations of the group page are shown in Figure 5.4.

When the users agree with a decision which is also regarded as a milestone of the project, they can add this decision into this group page via the green button “Add new milestone”. Then there will be a green sign on the blue arrow, which metaphors a milestone on the development path of the project. Users can add files, pictures and texts to describe the decision. If there is any question or comment regarding this decision, other users can add comments within the “New comments” block (Figure 5.4 A).

When comments added to one milestone, the sign turns red, indicating there is a comment needing to be addressed. People in the group can add replies to the comments, or they can initiate conversations to address the comment privately. When the comment is solved no matter publically or privately, everyone in the group page can mark the comment solved by providing the solutions or answers of the comments (Figure 5.4 B).

When the comment is solved, the sign turns green again, while the discussions of the comments are saved on this page for future references (Figure 5.4 C).

Figure 5.4 D shows the original group page without any expanded signs.

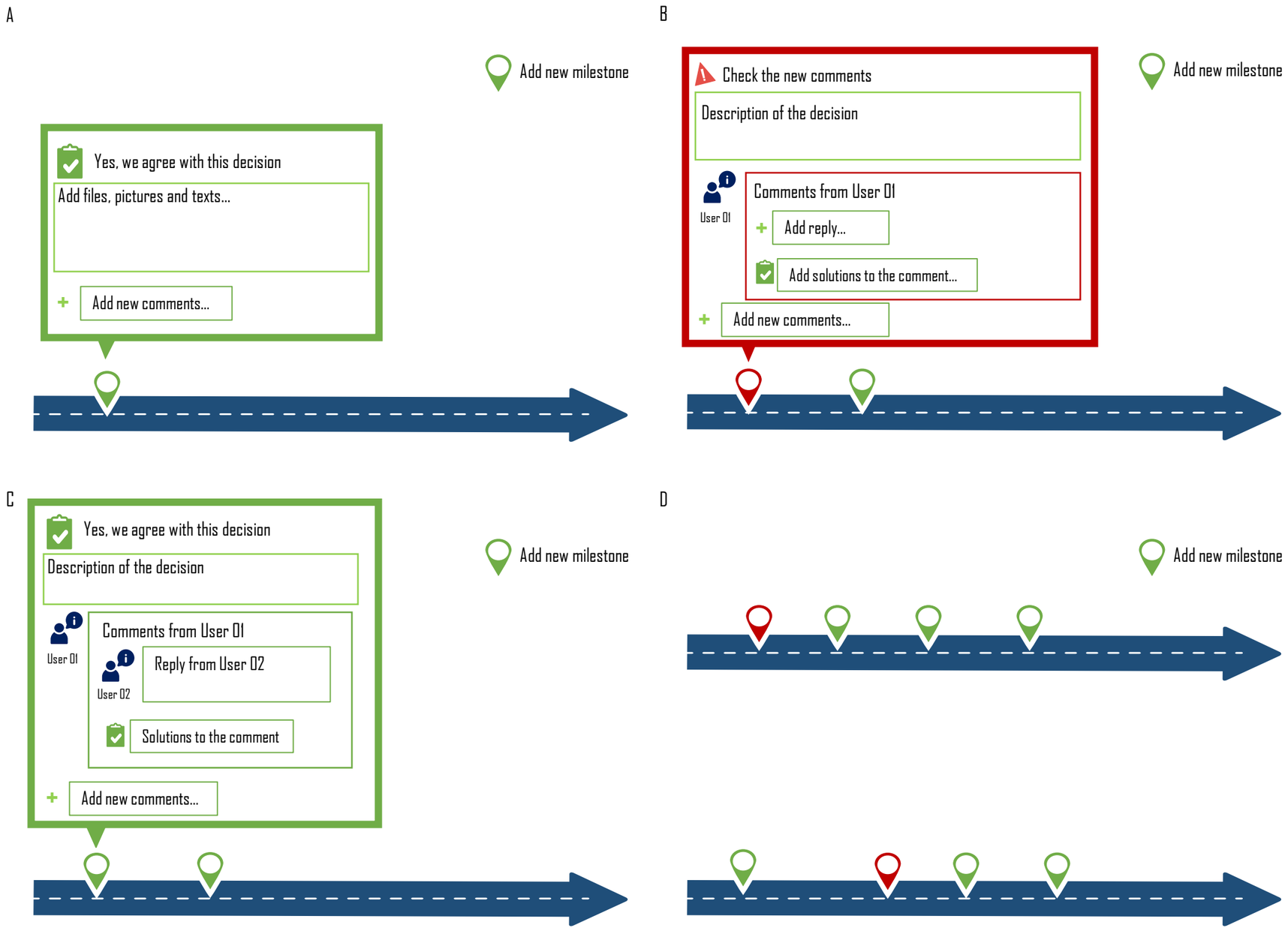

Figure 5.4 Interactive group page of the tool. A: Users can add group decision via the green button “Add new milestone” and add comments to the decision within the “New comments” block. B: Red sign indicates there is a comment needing to be addressed. Users can add response or solutions to the comment and mark the comment solved. C: When the comment is solved, the sign turns green again, while the discussions of the comments are saved on this page for future references. D: The original group page without any expanded signs.

06 Conclusions

The answers to the sub research questions and the answer to the main research question are summarised from previous chapters and illuminated in sequence in this chapter.

6.1 Answers to sub research questions

According to literature, what are the influential factors of engaging in a living lab network on an individual level?

The theoretical framework was the answer to the first sub research question. On an individual level, the theoretical framework of this research looked into the users-actors interaction within the living lab network. Along with the development of living labs, the users' role evolved from a passive one being observed or interviewed to an actively participatory one as a partner (Sanders & Stappers, 2008). This closer bonding between users and actors results in more intense boundary-spanning activities within a living lab. Through boundary-spanning activities, actors in a living lab try to establish relationships with external actors within the same field (Marrone, 2010). Coincided with the perspective of the social learning theory community of practise (COP), the boundary-spanning activities entails two main functions, one is to improve task performance while the other is to establish relationships with external actors (Huang et al., 2016). Translated in the language of COP, these two functions are improving own competence and increasing knowledgeability to the landscape (Wenger-trayner & Hutchinson, 2014).

According to the perspective of COP, these two functions of boundary-spanning activities can be realised through learning in the landscape (Wenger-trayner & Hutchinson, 2014). Learning in a living lab landscape is regarded as an ability to negotiate new meanings within a landscape of practice and to deal with boundaries between COPs, while developing its own competence in the landscape of practice (Wenger, 1999; Wenger-trayner & Hutchinson, 2014). And the learning process in the living lab landscape encompasses the dynamic construction of identity, particularly, the identity of competence and identity of knowledgeability. With the continuous process of identification, engaging in a living lab can be regarded as professionalisation as people obtain a better picture of how they are at work (Ruijters et al., 2015). The better picture of professionalisation includes the metacognition, that people are aware of the possibility and limitation of their cognitive abilities (Weggeman, 2015). The metacognition is one of the manifestations of knowledgeability, that is, by recognising the need of other competence, actors in a landscape are aware of their positions in the group and relations to other actors in the group. The result of learning is the reshaped professional identity, which includes the understanding of own expertise and the knowledgeability to the landscape.

Thus, on an individual level, an important element of engaging in a living lab network is the process of identification in which the identity of competence and knowledgeability develop continuously. Different professional identities which incorporated the institutional frames of various organisations are is usually the source of tensions between various actors (Ruijters et al., 2015; Wenger-trayner & Hutchinson, 2014). According to COP, three modes of identification facilitates the learning trajectory through the landscape, respectively engagement, imagination and alignment (Wenger-trayner & Hutchinson, 2014). Engagement manifests the actual interaction between actors while imagination addresses the assumptions and preparedness of the potential interaction. Alignment is the common ground of actors in a living lab landscape to move on the collaboration. These three steps of identification in a living lab landscape and the formation of identities of competence and knowledgeability are the influential factors of engaging in a living lab network identified during the literature study of this thesis. These influential factors were included in the interview questions and explored in practice during case study.

What is the ideal collaboration, according to people who engage in the collaboration of LL Instruments?

The second sub research question was explored during the interviews with stakeholders of the case LL Instruments of this thesis. The interviews were coded and the causal relations between all the codes were explored during the data analysis and presented as two causal loop diagrams. Identified from the causal loop diagrams, the critical nodes were the answer to this sub research question.

According to the people who engage in LL Instruments, the ideal collaboration is to involve various partners in the decision-making of projects. That is, in an ideal collaboration, viable decisions are made clinically, engineering and commercially as shown in Figure 4.5. In order to realise this real collaboration, actors in the living lab landscape need to direct the decision together into an overlapping area of feasibility scopes of all the expertise in the group.

What are the most important elements of an optimal mutual learning process within LL Instruments based on both theoretical and practical perspectives?

Synthesised from both theoretical and practical perspectives, the real collaboration elaborated above is the result of learning in the living lab landscape. The viable result is achieved by the knowledgeability as a facilitator (Figure 4.6). In order to make the decision within the feasibility scopes of all the expertise in the group, actors need to become knowledgeable of all the expertise in the group and grasp the relevance of other expertise to their own competence. During the interviews, interviewees mentioned that it was important to understand the expertise and objectives of each other, so that people can find a strong connection between each other. Without knowledgeability, participants could not constructively contribute to the decision-making of viable design as it becomes harder to identify the intersecting area of various expertise in the group.

Knowledgeability is also an important element of professional identity as mentioned in the chapter of the theoretical framework. The optimal mutual learning process encompasses the acquisition of knowledgeability to the landscape. According to COP, knowledgeability as a component of professional identity developed in the landscape can be facilitated by the three modes of identification, namely engagement, imagination and alignment (Wenger-trayner & Hutchinson, 2014). This leads to the answer to the last sub research question: a solution to insufficient knowledgeability.

What are the scenarios of solutions to support professionals to implement the final solution to achieve optimal mutual learning conditions?

The scenarios of solutions utilise the three steps of identification from the theory of COP. According to the theory, these three modes are interconnected and happen synchronously (Wenger-trayner & Hutchinson, 2014). However, during the co-session with stakeholders of LL Instruments, the sequence of three steps were identified as imagination comes first, then engagement finds out what is the reality and the last one is alignment, which is the result of imagination and engagement. These three steps become the content-based design criteria of designing the final tool, while the practice-based design criteria focus on the usefulness of the tool including how to intrigue people to use it and use it constantly because the development of identity is a long-term process.

Based on the design criteria, a concept of a digital tool was generated aiming to facilitate the identification of individuals engaging in the living lab landscape. The tool is a semi-structured logbook for personal and collective use with a digital format as an application on PCs or mobile phones. The tool materialises the three steps of identification into concrete inspiring questions to nudge the users to structure their conversations and incorporate knowledgeability into their professional identity in a living lab landscape.

6.2 Answer to main research question

The main research question of this thesis was formulated as below:

How can actors of LL Instruments optimally benefit from mutual learning in a living lab network on an individual level, according to the social learning theory on communities of practice?

On an individual level, the mutual learning process can be regarded as a process of identification, in which the professional identity includes the identity of own competence and the identity of knowledgeability to the living lab landscape is constantly developed. During the analysis of the interviews, while stakeholders could give a certain answer to the expertise they brought into the group, they were not always aware of the relevance of other expertise to their own work and the boundaries of their partner's expertise. This leads to the friction between various experts in the actual interaction because people are not sufficiently knowledgeable to other expertise in the group.

Thus, this thesis designed a tool to facilitate the process of identification to increase the knowledgeability of participants in two-way conversations, where various partners are inspired to reflect their interaction and through this way they incorporate the knowledgeability to other expertise in their professional identity.

In a nutshell, the actors of LL Instruments can optimally benefit from the mutual learning in a living lab by utilising the boundary-spanning activities as learning asset. During the learning process, actors incorporate the knowledgeability to all the expertise in the group into their professional identity. By being aware of the development of professional identity through noting down the learning process in the tool, the actors can obtain a clearer picture of their professional identity by constantly reflecting on and learning from their boundary-crossing interactions.

07 Discussion

In the discussion, the main results and the whole research process will be discussed critically according to the scientific rigour. Moreover, an outlook of this research will be given.

7.1 Discussion of the results

7.1.1 The final solution as a reflection of the theoretical framework

The concept of the final tool was generated from a series of literature-wise and practice-wise design criteria. The three steps of identification from the theory COP become the foundation of the individual page of the tool. The three blocks in the individual page make sure the user go through the imagination, engagement and alignment step one by one and encourage the users to reflect and learn from each conversation. What noteworthy is that the tool focuses on daily communication by using the format of a logbook, which comes from the interviews with stakeholders. Because in a dynamic living lab context, changes are rapid and profound, developments become more erratic and unpredictable (Hyysalo & Hakkarainen, 2014). In order to cope with the variability of the living lab and set up beneficial collaborative relationships, actors need to learn the context and reshape their corresponding identity fast and collaboratively. Thus, the daily use of the tool helps the users reshape their corresponding identity timely.

In the preparative imagination block, users need to think about the priority of their perspectives and imagine how will they interact with partners by answering the questions “What are the priorities of this topic from your perspective” and “To what extent do you think you need to explain your ideas to your partner”, respectively. By answering the first question, the users display their identity of competence; that is, they have prepared a set of expertise to contribute to this topic. By answering the second question, the users are aware of the level of knowledgeability of themselves and that of their partners. Because if people want to explain some specialised ideas to their partners from other disciplines, they need to prepare the conversation by imaging how easily their partners would understand, and knowing this level of readiness depends on each other’s knowledgeability. The tool requires the users to write down the answers to these two questions, and when they try to formulate their identity of competence and knowledgeability, they have a chance to realise what does these two abstract terms mean to them. Furthermore, being aware of their identity of competence and knowledgeability are also two aspects of a professional, i.e. shares his or her knowledge with others inside and outside the organisation and have metacognitive knowledge (Weggeman, 2015).

Furthermore, the inspiring question in the preparative imagination block may also induce curiosity and mindfulness about the upcoming conversations. Mindfulness is the receptive attention to what is happening in the present moment, which has been adopted as an approach for increasing awareness and responding skilfully to mental processes (Bishop et al., 2004), and it can be facilitated by curiosity (Kashdan et al., 2011). By increasing the curiosity and mindfulness about the conversations, the users would obtain a better learning experience when using this tool.

The engagement block allows users to see the difference of their professional identities from others’ by answering the questions “How does your identity and your partners’ identity differ during this conversation?” in the engagement block of the tool. The reason for emphasising the difference between partners is that the interviews of this research found out that most stakeholders can clearly express the common goal of their collaboration while not being explicitly aware of the differences. Differences may be the source of tensions, but the opportunity of reaping the benefits of boundary spanning activities lies in the process of becoming aware of these tensions and overcoming them (Benson, 1977). The difference

can be reduced by increasing the knowledgeability to other disciplines, which is the responsibility of both sides, the one is willing to explain and the other one is willing to learn. Through being aware of the difference and actively trying to reduce the difference by themselves or with the help of communicative solutions, actors enrich their professional identity with a high level of knowledgeability.

When the users are able to write down takeaways from their conversation in the alignment block, optimally they can be regarded as finished learning from their partners once. As time passes, the tool helps the users become knowledgeable to other expertise.

7.1.2 Significance of this research

This research enriched the study on the living lad methodology by shedding light on the identification process of participants. Through the identification happening during the human interaction within the living lab landscape, the users can obtain not only a better picture of the identity of competence, but also knowledgeability to the landscape which is regarded as an important benefit of participating in boundary-spanning activities. As illuminated in section 4.4, the knowledgeability played a significant role in reaping the benefit of boundary-spanning activities, i.e. co-creation of viable results within the feasibility scopes of all the expertise in the group. It suggested that knowledgeability can become an indicator of "boundary crossing competence", which manifests the ability to work and communicate across different practices (Augsburg, 2014). This thesis can provide insights to the research on education by quantising knowledgeability to improve and evaluate boundary-crossing competence.

This research also replenished the practical significance of the COP theory. In practice, the identity of competence functions as the feasibility scopes of expertise. The viable decision is generated from the overlapping area of all the feasibility scopes of expertise, in other words, a viable result must be feasible according to all the expertise in the group. And this objective is achieved by the knowledgeability, as presented in the intersecting area of all the identity of competence. The identities of competence are brought closer during the learning and interaction within the group, as a result, knowledgeability emerges when the identity of competence starts intersecting with each other as shown in Figure 7.1 below.

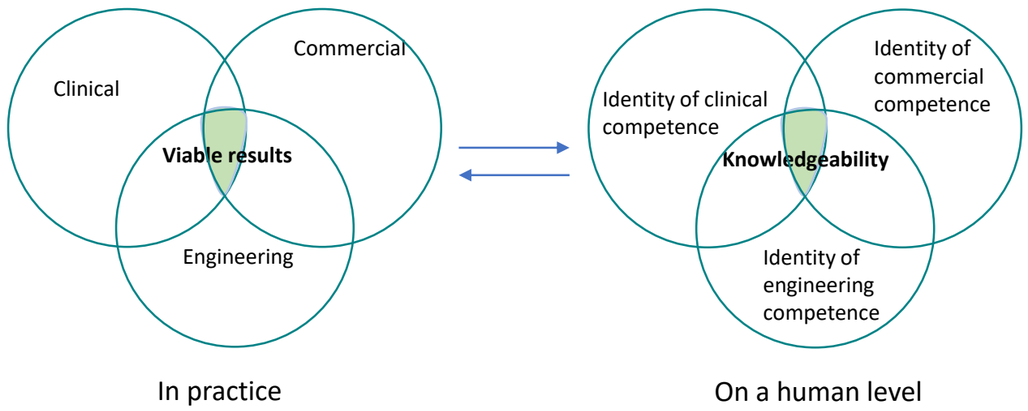

Figure 7.1 Translate the identity of competence and knowledgeability into the practical level.

In COP theory, the three modes of identification are considered interconnected and simultaneous. During the co-design session, the sequence of these three steps of identification was established as imagination first, then engagement and alignment came as the result of the previous two steps. Furthermore, imagination was regarded as the most important step because realistic imagination helps users manage their expectations on the collaboration and mitigate the potential conflicts of different perspectives. Guided by preparative imagination, users can better tackle the difference emerging during the conversations and turn the diversity into learning asset. The establishment of the sequence of three modes of identification could be implemented in designing other intervention of identification within a multidisciplinary context.

7.1.3 Discussion of the tool

The combination of individual and collective parts of the tool both increase the possibility of adoption. On the one hand, the individual part creates a safe environment for people to reflect their performance in conversations and note down their authentic thoughts without being judged. On the other hand, the collective part nudges everyone in the project group to adopt the tool by peer pressure as seeing everyone in the group is using it.

The usefulness of the tool highly depends on the willingness of users to use the individual page, yet not everyone has the habit of keeping a diary, or reflecting on their behaviour. Even though when they develop the habit to reflect, they can learn at high speed. However, if they start using this tool for their daily communication, it would not be difficult to form a habit because the tool has a comparatively high using frequency.

The tool focuses on building awareness by behaviour reinforcement. The writing behaviour can increase users' cognition to the difference and encourage users to address the difference by learning from it. However, they need first to have a certain level of recognition to the importance of learning in the group, developing identity in the group and paying attention to the boundaries between different disciplines, then they have the motivation to use the tool. Nevertheless, the tool does not involve any theoretical knowledge, but only practical communication tips. It would be much easier to start using this tool with practical functions and improving their professionalisation in terms of boundary spanning competence without knowing the theories behind. However, it may hamper the credibility of the tool as users may not believe the scientific rigour of it.

The tool gives users a large space to improvise, for example, they can only use the tool to set up a meeting agenda, but they can also use the tool to really reflect and improve the interdisciplinary interaction with communicative solutions. The high level of freedom may reduce the chance of using the tool as designed by the author. Some of the questions in the individual pages might be too broad to be answered as the author expected, and the tool does not give straightforward implications to the questions about how should the user address the difference to obtain optimal mutual learning. The tool only gives indirect guidance in communicative solutions as reference.

Moreover, as mentioned before, differences can be the source of tensions (Akkerman & Bakker, 2011). It also depends on the personalities and experience of the users to perceive the difference, as barriers mentioned in the co-design sessions (Appendix E). People who had a defensive personality, or an unhappy experience with a certain profession may not react positively to the difference as to regard it as

a learning asset. However, the tool cannot tackle this situation with ease yet. At this moment, the tool was designed for an ideal context, where users are all willing to learn from each other, respect others' perspectives, open and secure to different opinions or challenges. How will users use the tool in a not ideal situation remains unknown. Since interdisciplinary interaction also involved psychological process, the tool might need some psychological elements to better tackle non-ideal using context.

In a nutshell, in order to address the remaining problems discussed above, the tool needs iterative test and revise and in the future.

7.1.4 The outlook of the tool

The range of application of the tool can be broad because the tool facilitates daily communication during boundary-spanning activities. Thus, the tool can be theoretically suitable for any interdisciplinary projects in an academic context where people see the value of using communication tool to improve the quality of communication and are willing to reflect on their work constantly.

However, the usefulness of the tool is shackled by the lack of an evaluation system on the knowledgeability, which is the main objective of the tool. As mentioned before, knowledgeability can be an indicator of boundary-crossing competence. Thus, the most important future step of this research is to give definitions of different level of knowledgeability. With the scoring standards of knowledgeability, the tool can provide better insights into how knowledgeability has been improved and how professional identity has developed while using the tool. Evaluating abstract cognitive knowledge such as the development of knowledgeability or professional identity is difficult because different people would have a different perception of the development. In order to give scoring standards of knowledgeability, future research should look into the development of cognitive level during participating in a living lab landscape in a longer time frame from social psychological perspectives.

7.2 Discussion of the research methods

7.2.1 Translate literature in practice

In order to obtain a comprehensive picture of current research of living labs, the literature study started with a systematic literature review in Scopus. However, this first literature review gave a too broad scope to grasp the overall perspectives of living labs. After narrowing down the scope of this research into the individual level, the second wave of literature research applies narrative literature research because several topics were identified and not reviewed. In this way, the most important and relevant literature is found.

The theoretical framework of this thesis was basically built on the theory of COP from the book Learning in landscapes of practice (Wenger-trayner & Hutchinson, 2014). Meanwhile, the content-based design criteria were also solely from the theory of COP. This may result in this thesis with a weakness of lack of richness of literature. However, while exploring the application of the COP theory in the realistic context of the living lab, this research gave an example of using COP as a guideline to improve the mutual learning process in a living lab landscape. It also translated the theoretical process of identification into a concrete tool to increase knowledgeability of participants.

Finding the connection between theories and reality was difficult at the beginning of this research. As shown in the chapter of methods, the literature study proceeded the case study. This is theoretically logical because the theoretical framework could provide a scope to view the case study. However, in practice, a literature study without a preliminary understanding of the case made the literature study become purposeless and too broad to grasp. Thus, starting the literature study and informal interviews with key stakeholders of the case at the same time could significantly reduce the sense of uncertainty at the beginning of this thesis and make the literature study more efficient. During the whole period of the thesis, one noteworthy takeaway is that deductive social science research is a process to explore the interplay of theories and reality. In other words, the theories provide a lens to view the reality while the reality in return enriches the practical manifestation of theories in practice.

7.2.2 Interviews & Co-design sessions

The interviews were conducted with six stakeholders from different organisations of the case study. Because of the exploratory nature of the research and a diversity of participants, the results of this research are still reliable with a small number of participants.

All the interviews were transcribed and open coded. Even though there were some suggested codes next to the interview questions, basically all the codes emerged during the coding of transcripts. The iteration occurred during the coding process led to a more and more structured hierarchy of code groups and themes. A clear and exclusive structure of code trees made the exploration and visualisation of their causal relations easier.

The co-design sessions were conducted individually with interviewees of this thesis and communication professionals with whom the progress of this thesis was constantly updated. At the beginning of the co-design sessions, a 15-minute presentation of the results was given in order to help the participants recall the context and start thinking along with the author. After the presentation, they were invited to share their interpretation of the results. These presentation sessions with interviewees and communication professionals provided valuable supplements to the analysis and proved the validity of the results. The scenario prepared for translating the design criteria also helped participants interpret the design criteria. In order to avoid the risk of the scenario leading participants to illusory interpretation, the original formulations of the design criteria were also presented during the co-design sessions. This refrained the biased influence of the author's own perception on participants.

During the period of this research, physical co-design sessions were unrealistic because of the social-distancing policy. Because it was difficult to arrange a time slot for multiple participants to a meeting, the co-design sessions of this research performed with one participant every time. This might lead to less innovative solutions to the design criteria since participants lost the opportunity to be inspired by others. Meanwhile, multiple separate co-design sessions also resulted in more time spent on processing the co-design sessions because the author needed to transfer the solutions from action forms to a gathering morphological chart.

7.2.3 The final concept of the tool

Because the constraint of time, the development of the tool stopped in the final concept. And it was impossible to make a prototype of application within the time of this thesis and current capability of the author. However, the visualised prototype was discussed and improved with a fellow student and supervisor of this thesis, and their suggestions were integrated into the final concept of the tool.

In this thesis, because of limited time, the author came up with the three concepts based on her own experience and suggestions from interviewees. The evaluation and selection of the best concept was also conducted by the author alone even though the evaluation methods were discussed with the first supervisor of this thesis. Thus, the final concept might be strongly influenced by the author's biases and preferences.

Thus, in the future, the tool should be tested with more stakeholders of the case study with preferably a prototype of the application to increase the reliability and usefulness of tool further. Meanwhile, as the tool have a broad potential range of application, it is also worthwhile to test the tool in the context of other interdisciplinary projects with such as engineering students.

One necessary function of further development of the tool is a quarterly reflection to examine the development of professional identity. Otherwise, the development of professional identity may be buried in minor quantitative changes, while the qualitative reshape of identity become invisible and neglected.

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