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Game Structure in Knowledge Co-creation

Master's Thesis

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Aalto University School of Science Degree Programme in Information Networks	ABSTRACT OF THE MASTER'S THESIS
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Abstract:

The importance of creating, refining and distributing knowledge has become a key topic in the 21st century as knowledge work is becoming more commonplace. In order to respond to increasing needs for managing knowledge and knowledge creation, a number of models and methods have been developed. Methods for supporting knowledge creation are especially needed at the boundaries of different organizations where the differences between backgrounds and practices act both as a barrier to and as a source of new knowledge.

This thesis studies the use of game structure in knowledge co-creation. This thesis develops new theoretical understanding on how game structure affects knowledge co-creation and how objects of collaboration act as elements of knowledge co-creation games. This thesis also provides a set of guidelines for developing games to better support knowledge co-creation.

In its theoretical framework, this thesis combines organizational and learning sciences to form a multidisciplinary approach to knowledge co-creation. The framework is complemented with the theories of mediating objects of collaboration and the use of serious games in learning and design.

The empirical case study of this thesis examines a knowledge co-creation game for planning service co-development projects. Two instances of playing the game in inter-organizational and intra-organizational contexts are researched. The two instances of gameplay are video recorded and analyzed using interaction analysis to identify how game structure supports knowledge co-creation.

The results of this thesis suggest that game structure supports knowledge co-creation by providing structure for the interaction between players and also by providing the players with shared objects of collaboration that mediate knowledge co-creation. Furthermore, this thesis provides a framework for analyzing multiplayer games as activity systems by identifying the game states that the players interact with as the objects of collaboration. The game states provide a novel framework for studying collaboration in game structure.

Keywords: knowledge co-creation, serious games, game-based learning, objects of collaboration, service co-development

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Tiivistelmä:

Tiedon luomisen, jalostamisen ja jakelun merkitykset ovat kasvaneet huomattavasti tietotyön yleistyessä 2000-luvulla. Tiedon luomisen ja hallinnan haasteisiin on luotu useita malleja ja menetelmiä. Tiedon luomisen tukemiseen käytettäviä menetelmiä tarvitaan erityisesti tiedon yhteisluomisessa, jossa yhteisöjen käytäntöjen väliset erot ovat sekä uhka että mahdollisuus uuden tiedon luomiselle.

Tämä tutkimus perehtyy pelirakenteen vaikutukseen tiedon yhteisluomisessa. Tutkimus kehittää uutta ymmärrystä pelirakenteen kyvystä tukea tiedon yhteisluomista, sekä yhteistyön kohteiden roolista osana pelirakennetta. Tutkimus tuottaa myös suosituksia, joiden avulla tiedon yhteisluomista tukevia pelejä voidaan kehittää.

Tutkimuksen teoreettinen pohja muodostaa monitieteellisen kokonaiskuvan tiedon yhteisluomisesta yhdistämällä organisaatio- ja oppimistieteitä. Tutkimus tuo tähän teoriapohjaan lisäksi yhteistyön kohteiden tutkimuksen sekä hyötypelien tutkimisen oppimisessa ja muotoilussa.

Tutkimuksen empiirinen osa tarkastelee tapaustutkimuksena yhtä tiedonluomispeliä, jota käytetään palveluiden yhteiskehittämisprojektien suunnitteluun. Tutkimus koostuu pelin kahden käyttötilanteen analysoimisesta organisaatioiden välisessä ja sisäisessä kontekstissa. Tutkimuksen kaksi pelaamisen tilannetta videoidaan ja analysoidaan käyttäen vuorovaikutusanalyysimenetelmää. Tutkimuksen empiirisessä osassa tunnistetaan videoaineistosta miten pelirakenne tulee tiedon yhteisluomista.

Tutkimuksen tulosten perusteella pelirakenne tukee tiedon yhteisluomista tarjoamalla rakenteen pelaajien väliselle vuorovaikutukselle ja tarjoamalla pelaajien käyttöön jaettuja yhteistyön kohteita. Tutkimuksessa kehitetään teoreettinen kehys, jossa pelin sisäiset tilat tunnistetaan pelirakenteen sisäisiksi yhteistyön kohteiksi. Pelin tilojen tutkiminen tarjoaa uuden teoreettisen kehyksen, jolla toiminnan teoriaa voidaan hyödyntää yhteistyön tutkimisessa pelirakenteen sisällä.

Asiasanat: tiedon yhteisluominen, hyötypelit, peli-perustainen oppiminen, yhteistyön kohteet, palveluiden yhteiskehittäminen

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Play cannot be denied. You can deny, if you like, nearly all abstractions: justice, beauty, truth, goodness, mind, God. You can deny seriousness, but not play.

– Johan Huizinga, Homo Ludens

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I INTRODUCTION

1. INTRODUCTION

This thesis studies the use of game structure in knowledge co-creation: how a game-like environment helps us create knowledge and focus on shared objectives. The study is conducted through theoretical and empirical analyses focusing on how game structure and objects of collaboration shape the collaboration and the results of knowledge co-creation. The empirical case data of this study consists of playing a specific knowledge co-creation board game that is analyzed using a theoretical framework consisting of knowledge co-creation, objects of collaboration and collaborative games as activity systems.

The theoretical contribution of this thesis is to provide knowledge on how game structure affects knowledge co-creation and how objects of collaboration act as part of knowledge co-creation process in a knowledge creation game. The practical contribution of this thesis is to provide results on how knowledge creation games should be developed to better support knowledge co-creation.

This chapter outlines the research setting of the study and establishes the research gap the study aims to fill. Additionally, this chapter presents the research problem and theoretical research questions, and outlines the structure of this thesis. The three research questions are presented in this chapter for the literature review of this thesis in part II. The objectives of the study are also discussed in terms of theoretical and practical contribution.

1.1. BACKGROUND AND MOTIVATION

The importance of creating, refining and distributing knowledge has become a key topic in the 21st century as traditionally industrial economies have transformed into predominantly service-based knowledge economies (Powell and Snellman, 2004). As the cost of production has fallen due to advances in technology and the global access to low-cost labor, the value-adding tasks have shifted from manufacturing into design, engineering and other knowledge-intensive tasks. In these tasks both the input and output of work is information and the work consists mostly of manipulating information and creating knowledge (Blackler, 1995).

I INTRODUCTION

To respond to the increasing needs for managing knowledge and knowledge creation, a number of models have been developed to model the creation and transfer of knowledge within organizations (Brown and Duguid, 1991; Nonaka, 1994; Orlikowski, 2002). Knowledge creation has been researched in many fields, including behavioral (Bereiter and Scardamalia, 2003; Bereiter, 2002), social (Engeström, 1987; Lave and Wenger, 1991) and organizational sciences (Bechky, 2003; Nonaka et al., 2000), each with their own discourse and areas of interest. As knowledge creation has been more widely researched, it has become clear that theories of knowledge creation need to approach the subject in a multi-disciplinary manner, bridging the gaps between existing discourses.

Methods for knowledge creation are especially needed at the *knowledge boundaries,* e.g. the meeting points of different organizations, which are simultaneously the source and barrier to innovation and knowledge creation (Carlile, 2002). Previously the research in the methods for supporting knowledge creation has included methods for gathering prospective user data through generative sessions in design (Visser et al., 2005) and collaboratively creating shared visions of organizational goals in social work (Kokko, 2006). Even though methods for collaborative knowledge creation vary widely according to each field of origin, existing methods have focused on bringing different perspectives and backgrounds together in order to create new knowledge (Brandt, 2006; Pöyry-Lassila et al., 2013).

The theory of knowledge co-creation has focused on observing how the objects of collaboration function in knowledge co-creation, as interaction in the modern world is increasingly mediated by material artefacts like information and communication systems. The role of material artefacts is highlighted especially in the field of design research, where design materials play a key role in enabling design (Kankainen et al., 2012). Even though the study of objects and artefacts is central to modeling knowledge co-creation, such objects cannot be studied on their own but instead have to be observed within the practices they are used (Orlikowski, 2002). Consequently, this thesis studies objects and artefacts within the context of actual collaboration instead of studying the artifacts themselves outside of the practices of the collaborators.

At the same time, both electronic and physical games are enjoying a steady rise into the entertainment mainstream of the 21 century (PwC, 2012). The use of games beyond entertainment has been demonstrated on multiple application areas in the

form of so-called "serious games" to increase engagement, effectiveness and empowerment of participants (Abt, 1987). Example areas of serious gaming include design games (Brandt and Messeter, 2004; Habraken and Gross, 1987), learning games (DeVries and Edwards, 1973) and gamification of non-game user experience (Deterding et al., 2011a; McGonigal, 2011). However, while games have previously been used as tools for facilitating collaboration (Brandt, 2006), the use of games has not been researched as a method for supporting collaborative knowledge creation. This invites inquiry into whether game structures could also be used to support knowledge co-creation processes.

This thesis studies the use of game structure as a method for supporting collaborative knowledge creation. Knowledge creation has been established as a key function of cross-boundary collaboration, and the use of games has been identified as a potential avenue for new methods for facilitating knowledge co-creation. However, while research exists on the ability of games to support learning (DeVries and Edwards, 1973) and planning (Abt, 1987), games have not been studied as a method for knowledge co-creation. This thesis aims to provide an example of games being used in the context of service co-development and provide theoretical groundwork for explaining and developing the ability of games to support knowledge co-creation.

1.2. RESEARCH PROBLEM AND THEORETICAL RESEARCH QUESTIONS

To address the research gap described in the previous subchapter, the research problem of this thesis is:

How does game structure support knowledge co-creation?

The research problem of this thesis is first studied through three research questions in part II, Theoretical framework, which consists of a literature review and a theoretical synthesis. The literature review discusses the theoretical framework of knowledge co-creation, objects of collaboration and collaborative game research. The literature review draws upon organizational and learning sciences, and design research to present different views on collaboration, knowledge co-creation and games. At the end of part II the research questions are refined for the empirical study.

In order to identify the theoretical framework for answering the research problem, the research problem is divided into three theoretical research questions (TRQ). The theoretical research questions for the literature review are:

TRQ1: How does knowledge co-creation take place?

TRQ2: What are the prerequisites for supporting knowledge co-creation?

TRQ3: How can games support knowledge co-creation?

At the end of part II, refined research questions are presented for empirical study. The refined research questions are based on the results of the literature review in order to compare empirical study results to relevant theoretical knowledge.

The objective of this thesis is to increase knowledge about the use of game structures in knowledge co-creation. The specified theoretical and practical objectives are as follows:

1. The theoretical objective of the study is to provide knowledge about how game structure could support knowledge co-creation as a tool. Additionally, the study aims to provide additional knowledge on how objects of collaboration are used in game structure.
2. The practical objective of the study is to advance the understanding of how game structure should be used to support knowledge co-creation. This understanding aims to develop games that facilitate knowledge co-creation in service co-development more effectively.

This study contributes to multiple fields of research studying knowledge creation and co-development, such as cross-boundary collaboration, serious games and service co-development. The practical contributions of this thesis are relevant for practitioners who design or use serious games in organizational contexts.

1.3. RESEARCH APPROACH AND SCOPE

The research approach of this study is qualitative. Qualitative research aims to understand social or human problems and their meanings for individuals or communities. Qualitative research addresses the complexity and uniqueness of situations related to human issues, and thus offers a possibility to examine the topic in depth and with an open-ended question setting. The analysis of qualitative data is

based on researcher's interpretations, and consequently is affected by the researcher's individual understanding of the research subject. (Creswell, 2009) The research objectives of this thesis answer questions of "how", as is typical for qualitative approach.

Case study method in general is used when the research is focused on the nature or reasons of an event or a phenomenon, the researcher has little control over events and the focus is on a real-life matter (Yin, 2009). Case study methodology fits the objective of this study to explain a phenomenon based on a collected set of data.

The research method of this study is a single-case study with a nested multiple-case study (Yin, 2009). This means that the single case of research is the study of a particular game, and the two nested cases are cases of using the game in different contexts. Including more than one contexts of use has multiple advantages over single-case studies as the conclusions made from one case of use can be contrasted with another to better understand the multiple variables affecting the cases of use and the results can be generalized further than with one case of use (Yin, 2009).

The cases of this nested multiple-case study have been selected by the researcher based on the ability of the cases to further theory on the subject with the intention of looking for cross-case similarities and differences (Eisenhardt, 1989). This thesis uses a case study to provide suggestions on generalizing the results of the case study across different contexts.

This study examines a single method for supporting collaborative knowledge creation between interdisciplinary, inter-organizational or otherwise diverse participants. The research context of the study is the ATLAS game, is a board game developed in the ATLAS research project at Aalto University. The ATLAS game combines service co-development content with game structure to facilitate the creation of a service co-development project plan and provide players with information about service co-development methods. The cases of this study are described in detail in Chapter 6.

The case data of this study consists mostly of video recordings of groups playing the ATLAS game at two game testing events organized by researchers in different contexts and with different participants. Video data presents an opportunity to capture the social interaction between the players and the game in detail, including

verbal and non-verbal speech but also gestures, poses and interaction with shared artefacts (Heath et al., 2010). The video data is analyzed according to the principles of interaction analysis (Jordan and Henderson, 1995), which focuses on the interaction between persons and artefacts. Other documentation from the workshops, such as game materials, photographs and written notes, are also used to support understanding of the events taking place on the video.

The video analysis method used in the study follows the method presented by Heath et al. (Heath et al., 2010) in which data is reviewed multiple times iteratively in three phases:

1. The preliminary review, which consists of looking through the data and establishing a content log to outline how relevant segments are arranged in the data.
2. The substantive review, in which the content log written during the preliminary view is used to investigate data more closely and classify sections based on the observed phenomena.
3. The analytic review, in which segments identified as important in the substantive review are analyzed in detail.

Abductive inference logic has been utilized in this study, also known as *interference to the best explanation* (IBE) (Ketokivi and Mantere, 2010). The key feature of abductive reasoning is the iterative combination and comparison of empirical and theoretical understanding throughout the research (Dubois and Gadde, 2002). Unlike in purely inductive or deductive, theory and observation are not tested against each other over the course of the study to determine the credibility of the chosen theory. Instead, theory and observation are studied in cycles as explaining each other to reach the best theoretical explanation of the studied empirical phenomenon (Kovács and Spens, 2005). In abductive logic the role of the researcher as the final arbiter between competing explanations is explicitly accepted as a pragmatic element of reasoning (Ketokivi and Mantere, 2010).

Abductive reasoning is typical in case studies, as it deepens the understanding of the case and allows for better construction of theory towards theoretical, not statistical, generalizations (Eisenhardt, 1989). Abductive reasoning played a key part in the research process as a guiding principle in choosing the theoretical framework that

has the best explanation power for the empirical observations and reflecting the theoretical concepts when conducting the empirical analysis.

1.4. STRUCTURE OF THE STUDY

This thesis is divided into four parts: introduction (I), theoretical framework (I), empirical study (III) and conclusions (IV). The structure is visualized in Figure 1.

I INTRODUCTION	II THEORETICAL FRAMEWORK	III EMPIRICAL STUDY	IV CONCLUSIONS
1. Introduction	2. Knowledge co-creation 3. Objects of boundary-crossing collaboration 4. Collaborative games as activity systems 5. Theoretical synthesis	6. Empirical study description 7. Data collection and analysis 8. Empirical findings	9. Results 10. Implications of the study 11. Evaluation

Figure 1 – The structure of the thesis

The first part of the thesis describes the background and motivation of the thesis. Additionally, the chapter presents the research problem, objectives, preliminary research questions, methods and scope of the study.

The second part of this thesis is a literature review of the relevant scientific literature for understanding the examined phenomenon. The review discusses the theoretical roots of knowledge co-creation, objects of collaboration and collaborative games as activity systems. At the end of part II, refined research questions are presented for empirical study.

The third part of this thesis describes the two case studies of this research and how data gathering and analysis was conducted. At the end of part III, the findings of the study are presented, and the research questions are answered.

The fourth part of this thesis discusses the theoretical framework and the empirical findings, and presents the conclusions of the study. Implications of the study are

discussed and topics for future research are discussed. At the end of the thesis, the results of the study are evaluated.

II THEORETICAL FRAMEWORK

This part consists of a literature review which presents the relevant theories of knowledge co-creation, objects of collaboration, and game studies for this thesis.

First, the review describes knowledge creation as a collaborative social process and introduces central models for understanding knowledge co-creation (Chapter 2). Second, the review describes a model for analyzing the role of objects and artefacts knowledge co-creation (Chapter 3). Third, the review presents the relevant literature on game studies for the analyzing the potential use of games in knowledge co-creation (Chapter 4). Last, the synthesis describes models for object-mediated knowledge co-creation and game structure (Chapter 5).

2. KNOWLEDGE CO-CREATION

This chapter presents a theoretical framework that defines knowledge co-creation as social collaborative knowledge creation and introduces models for analyzing knowledge co-creation processes. First, social and dialogic aspects of knowledge co-creation are discussed with the theory of innovative knowledge communities and three models of the social knowledge creation models that underpin it: knowledge creation spiral, expansive learning and knowledge building (2.1). Second, a theory that describes knowledge transformation as a process of knowledge co-creation is presented to link knowledge co-creation to observations (2.2). Finally, trialogical learning is described as a complementing object-oriented model of knowledge co-creation from the perspective of learning science (2.3).

2.1. KNOWLEDGE CO-CREATION AS A SOCIAL PROCESS

Research in collaborative learning has arisen from criticizing the intuition-based *acquisition metaphor* of knowledge, according to which knowledge presides in the mind of an individual and learning in an activity of acquiring personal knowledge (Sfard, 1998). However, there is a strong consensus that learning is not purely a personal matter and individuals have to be analyzed as the members of a wider community when researching learning (Bereiter and Scardamalia, 2003; Brown and Duguid, 1991; Paavola et al., 2004). This also means that knowledge creation, as a theory of learning, is also always embedded in social interaction.

II THEORETICAL FRAMEWORK

This thesis approaches the process of knowledge co-creation from a practice-based, socio-cultural viewpoint (Lave and Wenger, 1991; Orlikowski, 2007). Knowledge is seen as practices, the ability of communities to reach goals through identified methods, and practices as a form of knowing is inseparable from acting (e.g. Knorr Cetina, 1997; Orlikowski, 2002). The creation of knowledge is therefore the development of practices an individual can perform as a member of a community.

Innovative knowledge communities (Hakkarainen et al., 2004; Paavola et al., 2004) are communities able to develop their own practices through the development of shared artefacts (Hakkarainen, 2009). Hakkarainen et al. (2004) argue that earlier models of knowledge co-creation proposed by Nonaka and Takeuchi (1995), Engeström (1987), and Bereiter (2002) are all different examples of innovative knowledge communities. The innovative knowledge community is therefore not a separate or synthetic model but instead a proposed classification to point out the similarities of the three models of knowledge creation. Hakkarainen et al. (2004) also list specific key commonalities between the three knowledge creation models that define innovative knowledge communities: 1) avoiding Cartesian dualism between an actor an environment, 2) viewing knowledge creation as a social process, 3) emphasizing the role of individual subjects in knowledge creation, 4) extending knowing beyond propositional knowledge, 5) recognizing the importance conceptual artefacts, and 6) interacting through shared objects (Paavola et al., 2004).

In this thesis, the concept of innovative knowledge communities describes a community where knowledge co-creation takes place as a deliberate effort to collaborative create new knowledge (Hakkarainen et al., 2004). The common features of the theories by Nonaka and Takeuchi (1995), Engeström (1987), and Bereiter (2002) which form the basis of innovative knowledge communities are used to define the key features of innovative knowledge communities that must be present and should be supported in order to facilitate knowledge co-creation. The key elements of the three contributing theories are presented in Table 1. The theories are described in detail in the following paragraphs.

Table 1 – Elements of theories contributing to innovative knowledge communities (Hakkarainen et al., 2004).

	Nonaka & Takeuchi (1995)	Engeström et al. (1999)	Bereiter (2002)
The role of individual expertise	Individuals are taken as given, individuals create knowledge	Social theory of mind, individuals embedded in sociocultural contexts	Theory of expertise
Main focus	Tacit knowledge	Knowledge embedded in practices	Knowledge objects
Type of processes studied	Emphasize bodily processes, personal experience	Emphasize material object-oriented activities	Emphasize solving of knowledge problems
Source of innovation	Transforming tacit knowledge to explicit knowledge	Overcoming tensions, disturbances, and ambiguities by expansive learning	Working deliberately for extending and creating new knowledge objects
Scope of framework	Different ontological levels from individuals, groups to communities, and organizations	Activity systems and networks of activity systems	Knowledge-building communities and organizations

In the first theory, Nonaka and Takeuchi (1995) studied knowledge creation in organizations and how knowledge is converted within the organization. In their widely known *knowledge creation spiral* (Figure 2), also known as the Socialization, Externalization, Combination, Internationalization (SECI) model, Nonaka and Takeuchi emphasize the contrast between *explicit* and *tacit knowledge*.

Explicit knowledge is propositional in nature and can be written down, while tacit knowledge consists of personal experience, values and emotions and cannot be immediately expressed verbally (Nonaka, 1994). Typical examples of explicit knowledge include knowledge about organizational structures, competence to use certain technologies and other knowledge that can be written into a manual. Tacit knowledge includes intuition regarding what has been accepted as a solution to a problem situation, interpersonal relationships and other experiential knowledge that

is usually learned only by being mentored or participating in a community's activities.

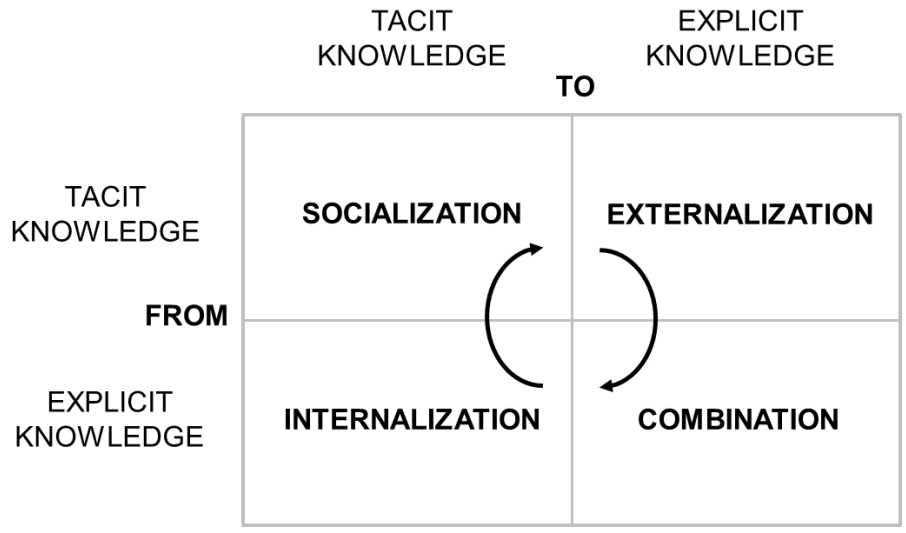

Figure 2 – The knowledge creation spiral, by Nonaka and Takeuchi (1995).

According to Nonaka and Takeuchi (1995), the knowledge creation spiral (Figure 2) describes four steps of *knowledge conversion* within an organization: socialization, externalization, combination and internalization. Socialization is the activity of sharing tacit knowledge between individuals, and it happens within a workspace as a result of working in a workplace community or in an apprenticeship. Externalization is an activity where an individual converts his tacit knowledge into explicit knowledge by using metaphors and analogies and is thus the most important phase regarding knowledge creation. Combination is an organizational activity in which large amounts of explicit knowledge can be combined and distributed with other explicit knowledge via a knowledge management system. Internationalization is the phase where the explicit knowledge is converted into an individual's tacit knowledge by applying the knowledge in practice and contextualizing it with previous experiences. (Nonaka and Takeuchi, 1995; Nonaka, 1994) An organization's ability to create knowledge is dependent on enabling this cycle by providing *ba*, the space in which knowledge conversion can take place (Nonaka et al., 2000).

In the second theory, Engeström (1987; 1999) studied knowledge co-creation in learning and introduced the model of expansive learning (Figure 3). The expansive learning cycle describes the process through which a group develops its social practice by questioning its current position and proceeding to analyze and improve

the current practices. In contrast to the Nonaka and Takeuchi's model, the cycle in Engeström's model is self-triggered by the actors when they question the current practices instead of an organizational process driving knowledge creation (Hakkarainen et al., 2004).

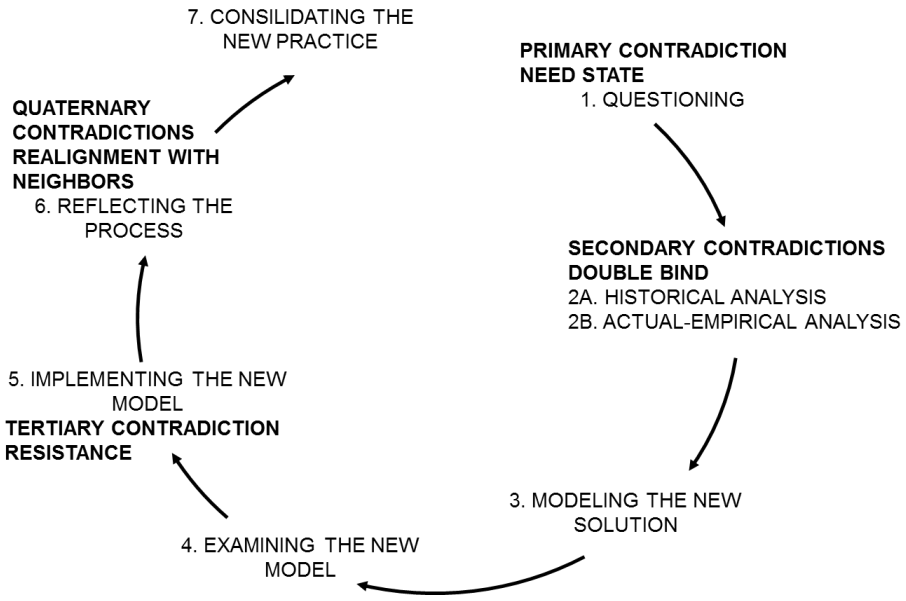

Figure 3 – The expansive learning cycle by Engeström (1999).

In expansive learning, participants of a group question first the existing practices i.e. way of working or knowledge about activities. Second, the participants analyze the historical context of their situation and how they perceive their current situation. Third, the participants model a new way of working that would solve the contradictions identified in the first step. Fourth, the participants examine the new model and how it could work in their context. Fifth, the participants implement the new model to test how it works in practice. Sixth, they reflect on the process and evaluate how the model was implemented. Finally, the new practice is consolidated so that it can be fully utilized. Even though the expansive learning cycle is pictured as a process, all steps do not necessarily appear in all instances and the steps may appear in different order (Engeström et al., 1999).

In the third theory, Bereiter's (2002) model of knowledge building is a model that emphasizes the role of creating ideas and concepts. These ideas are called *conceptual artefacts,* and they act as both the outcomes of knowledge co-creation and the main tools of reaching them (Bereiter, 2002). Knowledge building model describes a community that engages in deliberate knowledge co-creation by creating shared

conceptual artefacts: mental structures that can be used like tools to produce more knowledge (Bereiter, 2002).

Examples of conceptual artefacts include scientific theories and symbolic relations, as in the case of organizing scientific research around the testing and use of theoretical models. Proposed as a model for knowledge work in organizations, knowledge building was intended to propose a new way of education that would center on students' collaborative pursuit of knowledge by designing and improving solutions by themselves (Bereiter and Scardamalia, 2003). A key feature of knowledge building model for this thesis is the explicit assumption that ideas can act as mediating tools to reach further knowledge, and that inquiry is mediated by the objects developed in the collaboration.

In summary, each of the three models describes innovative knowledge communities, but emphasized different key features: tacit knowledge, knowledge embedded in practices and mediating knowledge objects. The theoretical framework of social knowledge co-creation is used in this thesis to analyze knowledge co-creation as a deliberate, socially distributed process undertaken to create new knowledge.

2.2. KNOWLEDGE CO-CREATION AS KNOWLEDGE TRANSFORMATION

An often cited theory of knowledge co-creation is the theory of *knowledge transformation* (Carlile, 2004, 2002). Knowledge transformation describes knowledge co-creation as an object-oriented process that revolves around *boundary objects*. Boundary objects are objects that have meaning in multiple different contexts and therefore can be used to translate meaning between these contexts. The term boundary object was originally coined by Star (1989) and adopted by Carlile (2004, 2002) as the shared object with which knowledge is transformed. The boundary object makes it possible for collaborating groups from different backgrounds not only to translate their knowledge to another group, but also to engage in collaboration with the other group to transform their knowledge into the other group's context, resulting in new knowledge being created. The theory of boundary objects is explained further in Chapter 3.1.

Carlile (2002) calls the boundaries between contexts *knowledge boundaries*, the existence of which is closely related to the concept of *communities of practice*. A

community of practice is a group of people who share a problem area. A community forms around the problem and the members of the community gather and distribute knowledge regarding the problem area in the form of practices (Brown and Duguid, 1991; Lave and Wenger, 1991). Belonging to a community of practice enables specialization around that subject but the increase of tacit knowledge regarding the subject matter creates boundaries between other communities.

Carlile describes this knowledge boundary as "both a source of and a barrier to innovation" (Carlile, 2002, p. 442). The source of innovation is knowledge which is transformed from one context to another. The transformed knowledge is novel within the new context but also gains completely new meaning and use in the process of transformation compared to the source context. The barrier to innovation arises from the cost of having to learn about the other party and figuring out how to implement the knowledge in their own field (Carlile, 2004). From an organizational perspective, knowledge transformation is part of a cycle where knowledge retrieval, transformation and storage follow each other as an organization incorporates new knowledge (Carlile and Rebentisch, 2003).

Carlile's (2004) model of knowledge transformation is based on three levels of communication across boundaries: syntactic, semantic and pragmatic (Figure 4). The *syntactic level* uses a defined syntax between communicators as the precondition for understanding the signals of the other party, such as a shared vocabulary regarding a problem that multiple parties collaborate on. However, even if a common syntax is developed, the information can be interpreted differently as there are differences of kind in communication between communities. The *semantic level* admits that there are signals that are different in kind in addition to different in scope, and proposes that the hidden assumptions made by different communities need to be made explicit in order to translate messages from one community to another.

According to Carlile (2004), even as differences in kind are embraced, the implications are not dealt with, therefore requiring a third, *pragmatic level*. When communicating on the pragmatic level it is important to understand the consequences of the different and dependent elements. There are serious negative effects (i.e. costs) that arise from the fact that individuals have to let go of the knowledge they have accumulated within the practices of their community. Even after letting go of previous knowledge, additional costs are incurred from converting established knowledge to be used by the other side. (Carlile, 2004, 2002)

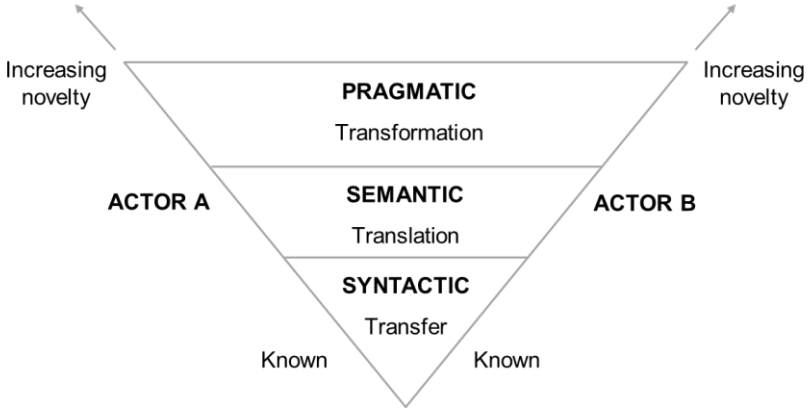

Figure 4 – Framework for managing knowledge across boundaries (Carlile, 2004).

While Carlile's theory of knowledge transformation includes individuals as communicators, the communication takes place on an organizational level, like between organizational units or departments (Carlile, 2002). In contrast, Bechky (2003) presented a personal level process of sharing meaning in cross-functional work as an additional viewpoint into knowledge transformation. Bechky (2003) studied the knowledge transformation process in interpersonal meetings on the factory floor and presented a process visualization of the knowledge transformation process, presented in Figure 5.

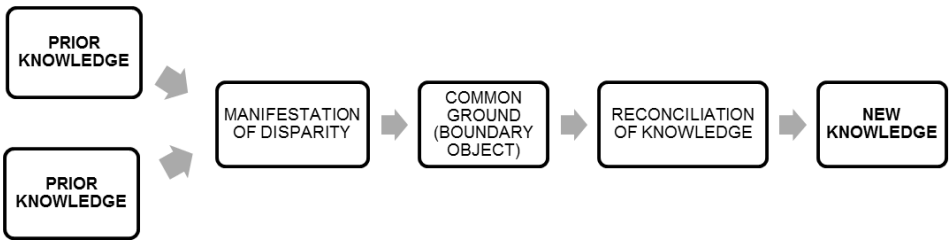

Figure 5 – Knowledge transformation process, adapted from Bechky (2003).

In Figure 5, Bechky (2003) describes the five steps of knowledge transformation that can be applied at personal or organizational level. At first, different parties have different prior knowledge regarding a specific problem within their context, like a machine designer and assembler may have different view into how a machine should be assembled. Second, a conflict or disagreement appears as the disparity between knowledge becomes apparent. A common ground must be established for meaning to translate and boundary objects can be observed as the common ground in these conflicts. For example, the machine parts being assembled might be used as the

boundary object between engineers and assemblers (Bechky, 2003). As both parties participate in transforming their knowledge regarding the object into the other party's context through the boundary object, knowledge is reconciled (Bechky, 2003). As an outcome new knowledge has been created as transformed knowledge has become novel in its new context (Carlile, 2004).

2.3. KNOWLEDGE CO-CREATION AS TRIALOGICAL LEARNING

Another view into knowledge co-creation is the theory of *trialogical learning* that focuses on co-creating knowledge through the collaborative development of shared objects (Paavola et al., 2004). Trialogical learning is also known as progressive inquiry in learning science. It has larger implications for organizing learning, but this thesis focuses on trialogical learning as a theory of knowledge co-creation.

Trialogical learning is a development of two earlier learning metaphors by Sfard (1998): *monological* and *dialogical learning* (Paavola et al., 2002). According to Paavola et al., monological learning is based on an acquisition metaphor of knowledge in which knowledge is acquired by a person and learning is a purely personal cognitive function that relies on external signals. In contrast, dialogical learning is based on a participation metaphor, in which participating in a community results in becoming a participant in a knowledge community. The two metaphors can exist side by side, with the acquisition metaphor describing the learning of propositional knowledge that can be explicitly stated, and the participation metaphor describing learning skills that involve tacit knowledge that is transmitted through practices (Paavola et al., 2004).

However, according to Paavola and Hakkarainen (2005) there is a need for a third metaphor of learning that reflects the co-creation of new knowledge. In trialogical learning, the participants do not seek to assimilate or attain access to a community but instead to develop new understanding and new knowledge (Paavola and Hakkarainen, 2005). This third view is closely related to the knowledge creation theories presented in Subchapter 3.1 because, like trialogical learning, all the models that form the basis for innovative knowledge communities aim to co-create knowledge as a learning outcome (Hakkarainen et al., 2004; Paavola et al., 2004). The relationship between the three metaphors of learning is visualized in Figure 6.

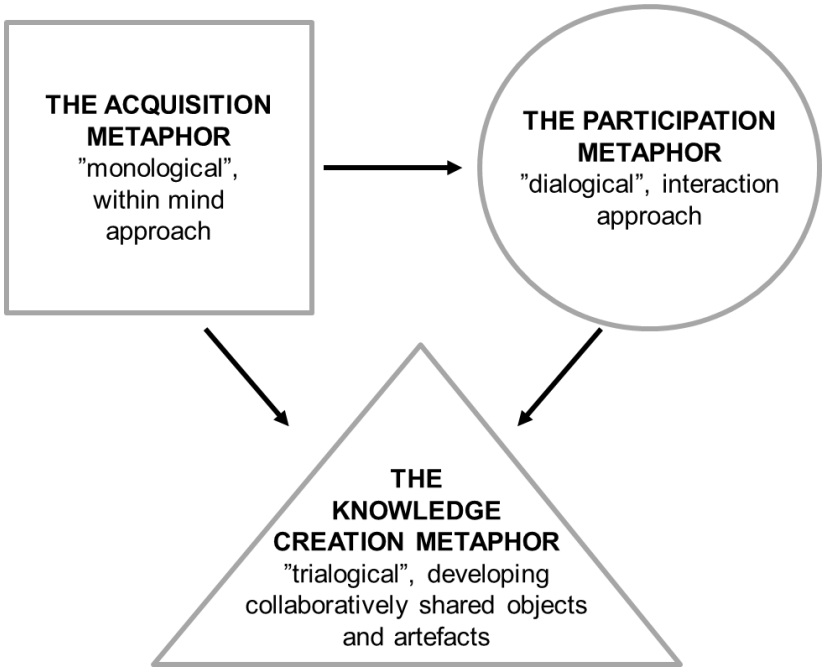

Figure 6 – Three metaphors of learning (Paavola and Hakkarainen, 2005)

Paavola and Hakkarainen (2009) describe six characteristics for trialogical learning approach:

1. Focus on *shared objects of activity*: epistemic artefacts (e.g., ideas, documents, designs), concrete material products (e.g., prototypes, design material) or practices (e.g., standard procedures, processes), which are developed in the collaboration
2. Sustained pursuit of knowledge advancement
3. Knowledge co-creation process taking place in mediated interaction between individual and collective activities
4. Cross-fertilization between knowledge communities
5. Technology mediation through material scaffolding (cf. Subchapter 3.1)
6. Development through transformation and reflection through the externalization and internationalization of knowledge in interaction between individual, object and community.

Trialogical learning takes place around shared *trialogical objects* that are developed within innovative knowledge communities (cf. 2.1) as part of knowledge co-creation. Examples of trialogical objects include written documents and visualizations that first help participants externalize their knowledge and then act as an object for

manipulation and collaboration. Trialogical objects as mediating objects of knowledge co-creation are elaborated on in Subchapter 3.2.

3. OBJECTS OF BOUNDARY-CROSSING COLLABORATION

This chapter presents an overview into different theories on the role of objects in collaboration and proposes a theoretical synthesis for examining objects of collaboration. Objects of collaboration are the tangible and intangible objects of activities collaborators enact on. In this thesis, different theories on objects of collaboration are studied based the objects' ability to support collaboration and knowledge co-creation.

First, a synthetic theory by Nicolini, Mengis and Swan (2012) is presented to describe the role of objects in cross-disciplinary collaboration. The role of objects in collaboration is described along with the four underlying theories it is based on: boundary object, material infrastructure, epistemic object and activity object (3.1). Second, a complementing theory for objects in collaboration is presented from the perspective of learning science, trialogical objects (Paavola et al., 2004) (3.2.). Finally, the theoretical approaches are compared and their mutual compatibility is addressed (3.3).

3.1. OBJECTS OF COLLABORATION

The theories presented in this subchapter are a collection of different viewpoints into how artefacts that are the objects of collaboration affect the nature and results of the collaboration. Even though the objects of collaboration might not be *the objectives of collaboration*, the fact that the activities involve and target discrete objects makes the objects themselves worthy of study. Multiple authors (Carlile, 2002; Hakkarainen, 2009; Orlikowski, 2007; Star, 1989) have proposed different models for objects of collaboration from very different viewpoints and within multiple contexts. This subchapter introduces a synthetic model by Nicolini et al. (2012) and presents the four theoretical models underpinning it: boundary object, material infrastructure, epistemic object and activity object.

Nicolini, Mengis and Swan (2012) argue for using multiple theories of objects that mediate collaboration instead of trying to apply a single model to explain all the situations where objects are used. The four theories Nicolini et al. have used are: *material infrastructure*, *boundary objects*, *epistemic objects* and *activity objects*. In their paper, Nicolini et al. contrast the four concepts of objects in terms of affordance

in cross-disciplinary settings, relationship to boundaries, completeness, conflict, novelty and historical conditions and divide them into three role levels of objects of collaboration: *tertiary*, *secondary* and *primary objects*. Individual objects take different roles depending on the phase and nature of collaboration, and the role is not directly tied to the individual artefacts that act as the objects of collaboration (Nicolini et al., 2012).

According to Nicolini et al. (2012), tertiary objects of collaboration are objects that are not the objective of collaboration but instead enable and mediate collaboration between individuals and groups, such as the information systems used in collaboration. Secondary objects are objects that are used in collaboration to coordinate the collaboration and translate knowledge between collaborators. Primary objects are the objective or motivator for collaboration. Collaboration may have multiple primary objects as collaboration is formed around primary objects in pursuit of a larger objective. The three levels are summarized in Table 2.

Table 2 – The role of objects in cross-disciplinary collaboration (Nicolini et al., 2012)

	Main function	Theoretical approach	Examples from a project
Tertiary objects of collaboration	Provide the basic "mundane" infrastructural support of collaboration	Infrastructure theory	E-mail system, phones, documents, built environment
Secondary objects of collaboration	Facilitate work across different types of boundaries	Boundary objects	Visual slides, bioreactor, shared analytical methods
Primary objects of collaboration	Trigger/sustain/motivate the cross-disciplinary collaboration, act as the objective of collaboration	Epistemic objects Activity objects	Bioreactor

According to Nicolini et al. (2012), objects that mediate collaboration can take different roles depending on the phase of collaboration. Objects can be physical artefacts or abstract objects, but physical or electronic artefacts tend to assume supporting roles whereas abstract models or objectives are not tied to physical artefacts, as seen in Table 2. Depending on the role the object takes at a specific time, objects motivate collaboration, allow participants to cross boundaries, and act as the infrastructure of collaboration (Nicolini et al., 2012).

Material infrastructure, also known as "scaffolding", refers to the ability of matter to support activities and processes. Material infrastructure in organizational science can refer to anything that affects practices, be it physical items or virtual environments (Carlile et al., 2013; Orlikowski, 2007). Scaffolding in learning sciences refers to the role of a tutor or a more competent peer as the one who "supports", as in "holds up in place", the actions of the learner until the learner has internalized conscious control of the new function or concept (Bruner, 1985). Scaffolding is also used as a model of supporting learning with technology like virtual learning environments (Muukkonen et al., 2005). In organizational science, Star and Ruhleder (1996) demonstrate the ability of material artefacts and information systems to scaffold knowledge creation as a part of organization practices. Star and Ruhleder emphasize the temporal nature of infrastructure – only once the object has been embedded in the routines and faded into the background of collaboration does the object become infrastructure. Compared to other objects of collaboration, material infrastructure is taken as granted and fades into the background to enable and shape collaboration rather than be the focus of it (Nicolini et al., 2012).

Boundary object is the most widely used theoretical concept out of those presented in Table 2. A boundary object is broadly defined as "an epistemic artefact that inhabits the cross-section of social worlds and satisfies the information requirements of each of them (Star and Griesemer, 1989)" (Nicolini et al., 2012). Boundary object was originally coined by Star (1989) to describe the systems used to combine heterogeneous knowledge from different sources despite differences in cases, situations and observers. The aggregated knowledge could then be accessed by anyone without having to understand the background of each observation. The term was adopted by Carlile (2004, 2002) in his model of knowledge transformation (see 2.2 Knowledge co-creation as knowledge transformation) as the shared object that makes it possible for collaborating parties that come from different backgrounds to not only translate their knowledge to a different person but to collaboratively transform their knowledge into the other party's context, resulting in new knowledge being created.

The concept of *activity object* is a development of Vygotsky's (1987) and later Engeström's (1987) work in activity theory, a psychological theory that emphasizes the object-oriented nature of all human activity and the ability of shared objects to motivate collaboration. The activity system described by Engeström (1987), depicted

in Figure 7, consists of a single actor, the object of activity, and their contextual factors.

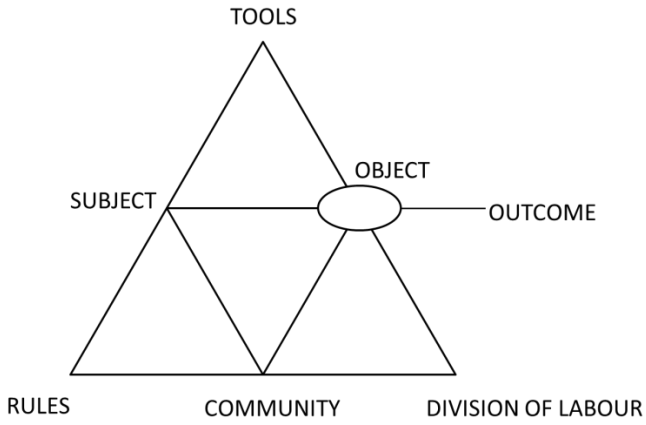

Figure 7 – Generic activity system (Engeström, 1987)

According to Engeström (1987), the *subject* in Figure 7 is the actor who is being analyzed. The *object* is the object of the activity "at which the activity is directed and which is molded or transformed into outcomes with the help of physical and symbolic, external and internal tools" (Engeström, 1996). The object can be a physical artefact, an epistemic artefact or other intangible object. *Tools* are physical and epistemic artefacts that mediate the subject's interaction with the object. The *community* is the group of social context the activity takes place in. *Division of labor* defines how activities are divided in relation to the community. *Rules* are the social constrictions of the activity. The *outcome* is the intended outcome pursued by the subject through the activity mediated by the object.

As an object of collaboration, an activity object is situated in multiple simultaneous activity systems while conceptualized independently by different actors (Engeström, 1987; Miettinen and Virkkunen, 2005). The fact that actors do not have to agree on properties of the activity object makes activity objects by definition emergent, fragmented, and contradictory (Miettinen and Virkkunen, 2005). The outcome of the collaborative activity can be conceptual or physical, like a service or a product, but even if the outcome is a shared and tangible, the activity object is being constantly negotiated between the actors' interests and sense-making processes (Nicolini et al., 2012). Because activity objects are conceptualized independently by different actors, the objects may hold potentially contradictory orientations, interests, and interpretations together, enabling the formation of a "community without unity"

(Miettinen and Virkkunen, 2005; Miettinen, 2005). A factor that makes the activity object theory stand away from the other three object theories is that the activity object theory is derived from a tradition that comes from the assumption that all collaboration is mediated by objects and that all objects mediate collaboration (Engeström et al., 1999).

Epistemic objects, or objects of enquiry, are objects that act as "placeholders" for gathering information about concepts or objects which are not known or understood. In scientific research, epistemic objects are central concepts like the concept of a molecule or a production system that are the subject of research, and the research itself modifies and develops the qualities assigned to the epistemic object. The attention-sustaining effects of epistemic objects are based on their ability to inspire desire to know more about them and the lack of fulfillment that their existence creates. (Knorr Cetina, 1999, 1997) The concept of epistemic object was introduced by Hans-Jörg Rheinberger (1997) as the epistemic thing. in experimental science, the epistemic thing represents that which is not known, in contrast to are well known technical objects such as measurement instruments (cf. material infrastructure). The experimental setup described by Rheinberger involves known technical objects and an epistemic object, in which the technical objects are assumed to function in a predefined way in order to observe the behaviors of the unknown or "epistemic" parts of the system to discover new qualities about them.

Epistemic objects drive collaboration by providing an object of desire or some other shared goal, and collaboration around epistemic objects is well captured in the description "collaboration as the organization of desire" (Nicolini et al., 2012). Pursuing a shared object of desire as the goal of collaboration is the basis for mutual recognition and a sense of belonging (Knorr Cetina, 1997). The sense of belonging is sometimes related to social conventions like colleagueship or a similar feeling of "playing on the same team". According to some writers, the existence of an epistemic objects widely affects the relationships between collaborators, creating a sense of responsibility towards the epistemic object resulting in a "proto-community" structured according to the qualities of the epistemic object that cannot be understood without its existence (Knorr Cetina, 1999). This sense of community could also provide a strong enough sense of belonging that collaborators would engage in knowledge transfer beyond conventional knowledge communities (Nicolini et al., 2012).

Epistemic artefacts are presented in this thesis separately as conceptually individual wholly or partially intangible pieces of knowledge shared between individuals that may have a material component. The definition of epistemic artefacts used in this thesis matches multiple different concepts in the literature, such as the epistemic nature of epistemic objects in contrast to technical objects (Knorr Cetina, 1997; Rheinberger, 1997). Other similar concepts include epistemic things (Rheinberger, 1997), conceptual artefacts (Bereiter, 2002), knowledge objects and others.

In this thesis, the prefixes "epistemic" and "knowledge" are used synonymously in this thesis as is evident by their etymological root in the Greek word epistēmē, meaning "knowledge, understanding". Epistemic artefacts are used to refer to both abstract concepts and the epistemic qualities of concrete objects (such as documents). These exists beyond an individual in multiple theories, such as in the work of cultural artefacts by Bereiter (2002). On the other hand, epistemic artefacts are used to refer to concrete things produced as part of knowledge creation that have epistemic qualities by containing or referring to knowledge. Definitions for all types of objects presented in this subchapter are summarized in Table 3.

Table 3 – Objects of collaboration

Term	Theoretical framework	Definition
Epistemic artefact	(Bereiter, 2002; Miettinen and Virkkunen, 2005)	A singular piece of knowledge that acts as the object of manipulation or reference and may be represented by a tangible object
Material infrastructure (scaffolding)	(Bruner, 1985; Carlile et al., 2013; Orlikowski, 2007; Star and Ruhleder, 1996)	Material support that enables practices by mediating collaboration without being the object of collaboration
Boundary object	(Bechky, 2003; Carlile and Rebentisch, 2003; Carlile, 2004, 2002)	Epistemic artefacts that have meaning within more than one context and translates meaning across them
Activity object	(Engeström et al., 1999; Miettinen and Virkkunen, 2005; Miettinen, 2005)	The emergent and fragmented object of collaboration that unifies collaborators without the need for negotiation or definition
Epistemic object	(Knorr Cetina, 1999, 1997; Miettinen and Virkkunen, 2005; Rheinberger, 1997)	The objective of collaboration to which new meaning and knowledge is added to and which is constantly renegotiated as collaboration progresses

The definitions given here are formed by the author based on the theoretical framework. The definitions are used in the theoretical synthesis (3.3) and empirical analysis (part III). Figure 8 describes the author's understanding on how different types of objects of collaboration mediate collaboration, based on the definitions presented in Table 3. Items #1 and #2 refer to individuals or groups that collaborate to reach objectives.

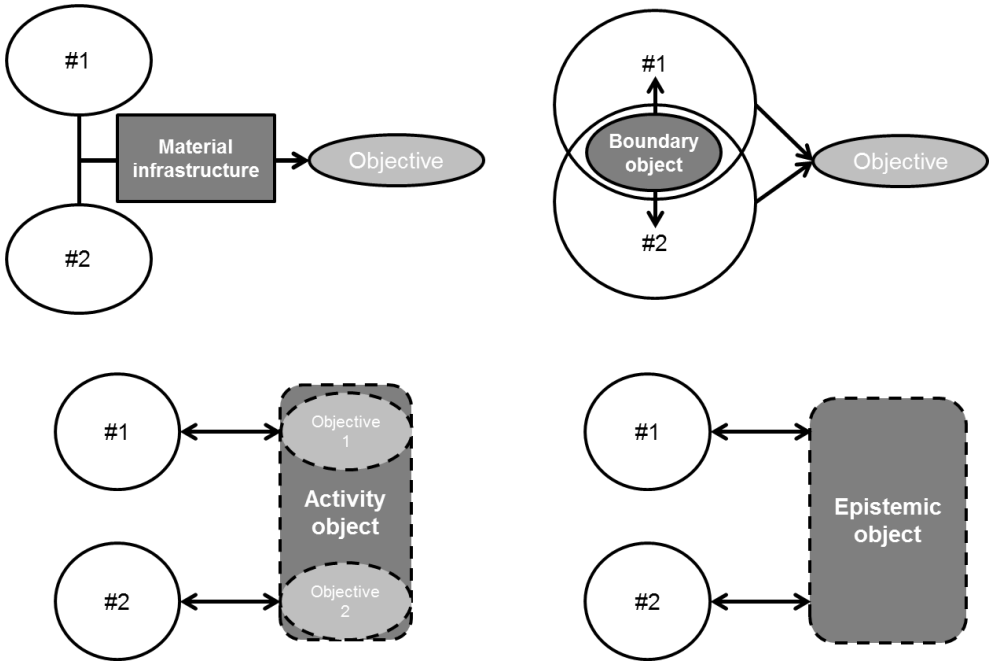

Figure 8 – Objects as mediators of collaboration

Objects of collaboration are presented in Figure 8 as mediators of collaboration i.e. how the collaborators are connected with each other and their objectives through the object of collaboration. On the upper left, *material infrastructure* acts as the common mediator between the collaborators, but does not motivate collaboration as a shared objective. On the upper right, a *boundary object* is a truly shared object of collaboration that mediates collaboration directly between the collaborators, but like material infrastructure, is not the objective of the collaboration. On the lower half, both an *activity object* and an *epistemic object* are targets of collaboration, and as such do not mediate direct interaction between the collaborators but rather motivate it through a shared target. On the lower left, an activity object exists as the observed "same" object the different parties are collaborating for while the actual objectives of

different parties may differ from one another. On the lower right, an epistemic object is an object of collaboration shared by the collaborators, in contrast to activity object.

Collaboration around an epistemic object is a process of adding new knowledge to the epistemic object without truly reaching it. Collaborators around an epistemic object recognize their shared object even if they have different ideas about the details or true nature about the epistemic object, and the epistemic object becomes an objective towards which the collaboration proceeds.

3.2. TRIALOGICAL OBJECTS

Trialogical object is a key feature in the theory of trialogical learning (2.3), in which participants engage in co-creating knowledge by developing shared objects. Trialogical objects are the objects of trialogical learning, a knowledge co-creation process that advances through the enrichment of trialogical objects by externalizing knowledge in writing and visualizations (Hakkarainen, 2009; Muukkonen et al., 2005). The observable characteristics of trialogical learning describes in Subchapter 2.3 imply that trialogical objects and trialogical learning are intertwined: trialogical learning takes place through trialogical objects and trialogical objects imply trialogical learning taking place.

Trialogical objects can be tangible or intangible depending on the nature and phase of trialogical learning, but they always exist as epistemic artefacts in addition to any material qualities (Muukkonen et al., 2005). Objects that might act as trialogical objects include epistemic artefacts (e.g., ideas, documents and designs), concrete material products (e.g., prototypes, design material) or practices (e.g., standard procedures, processes). Producing and developing these objects is the core activity of trialogical learning (Hakkarainen and Paavola, 2009).

Although trialogical objects are not generally defined using the term boundary object, in this thesis trialogical objects share many characteristics with the definition of boundary objects presented in Subchapter 3.1. Like boundary objects, trialogical learning and trialogical objects take place “at blurred interorganizational boundary zones” and aim to introduce “cross-fertilization of knowledge practices” (Hakkarainen and Paavola, 2009).

In a study described by Hakkarainen et al. (2010), epistemic artefacts within a development process “could serve multiple functions as objects of activity, as

mediators or as boundary objects between different expert practices within the network". Trialogical objects can therefore be said to act as boundary objects in the sense that they have meaning within multiple contexts and help translate and transform knowledge across that boundary. Because of the co-developed nature of trialogical objects, all parties participate in bringing the object closer to their own perspective contexts in the collaborative sense-making process. As a result, the trialogical object becomes meaningful across multiple participating parties and satisfies boundary object related needs effectively.

However, while reminiscent to the concepts of boundary object and epistemic object in the model presented by Nicolini et al. (2012) in the previous subchapter, trialogical objects have three distinct characteristics. First, unlike epistemic objects, trialogical objects manifest as artefacts (Knorr Cetina, 1997). Second, unlike boundary objects, trialogical objects are parts of a deliberate effort to create new knowledge as opposed to acquiring or communicating knowledge across boundaries (Paavola et al., 2004). Third, trialogical objects are formed to support knowledge co-creation and are developed during the knowledge co-creation (Hakkarainen and Paavola, 2009).

Trialogical objects are not described in the roles of objects by Nicolini et al. (2012) (Table 2), but the theoretical review suggests that trialogical objects can be used concurrently with the model as a specific kind of object of collaboration that is intentionally developed over the course of collaboration. The author suggest that a trialogical object takes on the role of primary or secondary object of collaboration depending on whether the specific trialogical object is the objective of collaboration (like when developing a prototype up to a set of criteria) or a means of pursuing the objective that mediates the collaboration (like a document describing a scientific theory). When considering the level of trialogical objects in terms of primary and secondary objects, one has to consider that on the one hand trialogical objects have similar characteristics with boundary objects, and on the other hand, trialogical objects have qualities similar to epistemic objects. Both epistemic objects and trialogical objects provide common ground for knowledge co-creation across disciplines and provide an intangible, constantly developed object to attach discovered qualities of a partially unknown object.

The relationship between trialogical objects and the levels of object of collaboration is elaborated further in the theoretical synthesis in Chapter 5.

4. COLLABORATIVE GAMES AS ACTIVITY SYSTEMS

This chapter describes at game research, a multidisciplinary field of research with contributing theories from social science, behavior science, computer science, and culture anthropology. Game research is presented from the viewpoint of games as a structure for supporting knowledge co-creation.

First, a definition of *what* is being looked at is presented by introducing selected literature for defining games. Second, a theoretical perspective for *how* games are looked at is explained using theory of activity systems in the research tradition of Vygotsky (1978) and Engeström (1987). Third, examples of games used in learning and organizational development are presented in the context of serious games, games that are played with the intent of achieving goals beyond the play itself. Finally, a synthesis describing game structure as an activity system is presented.

4.1. DEFINITIONS OF A GAME

In this study, the concept of *game structure* is defined as a system of practices, objects, and artifacts that enable game-like interaction between a game and its players, but also between the players themselves. Focusing on game structure allows studying the effects of designing knowledge co-creation processes as games and gain insight how existing games can be analyzed as knowledge co-creating systems.

The definition of a game is highly context-specific and open to interpretation. The core definition of a game used in this thesis was put forward by Salen and Zimmerman (2004), who enumerated ten key elements of games in entertainment and proposed a synthetic definition: "*Undertaking voluntary challenges that result in quantifiable outcomes*." McGonigal (2011) elaborated further on the four core characteristics that the definition includes:

1. It has goals: A game is a goal-oriented endeavor in which the players are aware of a desirable end condition and how to reach it, like scoring more goals than an opposing team.
2. It is limited by rules: The game sets unnecessary limitations on how the players can pursue the goal, like a limitation on how to move game pieces.
3. It provides a feedback system: The players have a feedback mechanism such as the number of points a player has scored.
4. It is based on voluntary participation: All games are voluntary by definition. All game-like behavior manifests only once a participant chooses to participate in a game instead of "going through the motions" out of necessity.

The definition is based on the precondition that games are a close cousin to free play, as suggested by Johan Huizinga (1949) in his pioneering book on the play element of human culture, and like free play, games are a deeply human behavior pattern that arises in certain conditions that can be formalized as individual games. Additional definitions of games usually refer to the spatially, temporally and socially limited nature of games, i.e. the defined borders of the "magic circle" that a game takes place in (Huizinga, 1949), or suggest games are created from player conflict or imitation of reality (Caillois, 1961). However, *pervasive games* that break the conventional limitations of games by expanding the scope, length or social rules of conventional games allow for a broader understanding of games (Montola, 2012; Montola et al., 2009). This thesis uses the broader definition of pervasive game definition.

The individual conditions that encourage or bring out game-like behavior have been characterized as *game elements*, like the existence of virtual worlds, game boards or scoring mechanisms in a tool or system. The nature and use of game elements has been extensively discussed in gamification literature, with definitions proposed by Deterging et al (2011a, 2011b) and Groh (2012). For this thesis, the definition and use of individual game elements are pushed to the background in order to situate knowledge co-creation *within* a game, not improve existing knowledge co-creation processes with game-like elements.

Many definitions of games are centered on the existence of rules as the defining feature of games (Salen and Zimmerman, 2004) but such definitions often fail to take into account the different types of rules. Out of the four game characteristics

described earlier, three are characteristics that one would assume to be part of the rules of the game: goal-orientation, limiting rules and feedback system. In this thesis, game rules are further divided into regulative rules, which limit the interaction between players and objects, and constitutive rules, which enable interaction with the game.

The concept of constitutive rules comes from social constructivism, which states that human institutions are systems of constitutive rules (Montola, 2012). The notable feature of constitutive rules is that they do not just restrict action but make interacting with the institution possible in the first place by creating the subject of the rules in addition to describing it (Montola, 2012). For example, a chess piece holds no role in the game of Chess without rules governing its use.

In contrast to constitutive rules, regulative rules are rules that constrict action (Montola, 2012). The most apparent regulative rules are often part of the explicit game rules, e.g. a rook in Chess cannot move backwards, but also include social rules, e.g. do not flip the table holding the game board.

4.2. GAMES AS ACTIVITY SYSTEMS

This subchapter looks at games in knowledge co-creation from two points of view connected to learning: *Zone of Proximal Development* (Vygotsky, 1978) and *activity systems* (Engeström, 1987). In this chapter, both theories are applied to describe how games can support learning and hence mediate knowledge co-creation.

The origins of *activity systems* lie with *activity theory* that originates in the seminal work of Lev Vygotsky (1978). The tradition of activity theory used in this study was developed further by Engeström (1987) in the study of object- mediated activity systems (cf. *activity objects* and Figure 7 in Subchapter 3.1). Activity theory has been applied in studying educational games as objects that enable the expansive development of practices (cf. *expansive learning* in Subchapter 2.1) in class room learning (Squire, 2002; Squire et al., 2005). Activity theory has also been applied in modeling online multiplayers games as activity systems (Paraskeva et al., 2010). However, different authors make different conclusions on how to model the relationship between the game, the players and the cultural-historical context in terms of activity systems. For example, both Squire (2002) and Paraskeva et al.

(2010) agree that activity system is a powerful approach to analyzing how games can be used to support learning, but disagree on what the object of activity is.

Vygotsky's work centers on developmental psychology and learning, for which he proposed the theory of *Zone of Proximal Development* (ZPD) (Vygotsky, 1978). ZPD is defined as the gap between the current independent abilities of a learner and what the learner can accomplish with the aid of a "more knowledgeable other". ZPD proposes that a child is able to learn skills by performing them with assistance before the child actually learns to apply them independently. What makes ZPD interesting in the context of games is Vygotsky's proposition that "[freeform] play creates a zone of proximal development of the child. In play a child always behaves beyond his average age, above his daily behavior; in play it is as though he were a head taller than himself" (Vygotsky, 1978). Like freeform play enables a structure where imitation and creative association is allowed to a greater degree than in daily life, game structure may allow a player to simulate future situations and learn new skills before applying them in practice as a structured form of play.

The use of game material also supports knowledge co-creation. Game material enables players to externalize their thinking by manipulating game pieces, be it by changing layout, orientation or position of game pieces or by in writing on designated game material. In terms of scaffolding (Orlikowski, 2007), a game structure is a technology that both guides the players forward but also gives them relevant information when they need it. The systematic objectification or materialization of ideas on paper helps generate novel ideas by providing a player to create additional stimulants for their thinking (Hakkarainen, 2009). Game designer Ralph Koster (2005) provides an insight into the relationship between the relationship between games and reality by stating that "Since [games] are formal systems, they exclude distracting external details. Usually, our brains have to do hard work to turn messy reality into something as clear as a game is." Continuous development of game material by the players in collaboration suggests that the game material provides even more stimulation (Hakkarainen, 2009) and holds games up as a potential structure for knowledge co-creation.

4.3. SERIOUS GAMES AS APPLICATIONS

The term *serious game* is non-definable but generally refers to the utilization of games for society, business or politics (Mayer et al., 2014). In this thesis, serious games are games that are used for something beyond the play itself, often as an aid for learning by keeping the attention of a learner over time, or by simulating future scenarios (Abt, 1987). Serious games are sometimes defined more strictly as games that have an educational function or that impart knowledge or skill upon the players, but such definitions fail to include other desirable outcomes such as art and rehabilitation (Breuer and Bente, 2010). This thesis studies the use of games to support knowledge co-creation and as such falls within the definition of serious games.

The use of the word "serious", despite its counterintuitive pairing with "games", is used to emphasize the use of games for purposes that are important and that have important consequences, such as education, industry and government. Serious is not intended to signify solemnity or somberness of games used in these contexts but rather to emphasize the ability of games to be "significant without being solemn, interesting without being hilarious, earnest and purposeful without being humorless, and difficult without being frustrating" (Abt, 1987). The ability of games to facilitate goals that would be considered "serious", such as learning, is illustrated by Koster (2005), who describes that the enjoyment of games comes from the flow of not having complete mastery but constantly developing to meet the challenge presented. "Fun from game arises out of comprehension… with games, learning is the drug" (Koster, 2005).

One notable tradition of serious games is *design games*, games used by designers as a tool of creating, collaborating and co-creating with end users and other stakeholders (Brandt and Messeter, 2004; Vaajakallio, 2012). Design games originate from the discipline of participationary design which highlights the need of designers to engage the future users of designed products and services in the design process (Sanders, 2002). Design games as a design tool emphasizes the use of games by the designer in relation to the users, usually to solicit information or engage in collaborative design (Brandt, 2006), and as such design games are often thought of as temporal tools that assist in the design process rather than objects to design in themselves. This can be seen in research design where design games are seldom

described in detail as formal games and players in design games are encouraged to interpret rules and game material very freely (Vaajakallio, 2012).

One of the earliest examples of design games was conducted by Ehn and Sjøgren (1991) who used board game elements to empower carpentry workers to make design proposals for the carpentry floor layout and the organizational structure. The use of a design game enabled the designers to involve the users of the carpentry in the design process even though the participants were not designers themselves. After Ehn and Sjøgren, the formats of possible design games have varied widely, ranging from board and card games to scenarios and narrative play according to different contexts (Brandt and Messeter, 2004; Ehn and Sjøgren, 1991; Kankainen et al., 2012).

To explore how game-like features support design games, Vaajakallio (2012) proposed the Play framework for analyzing design games. The Play framework describes design games as at the same time "a tool, a mindset and a structure", summarized in Figure 9.

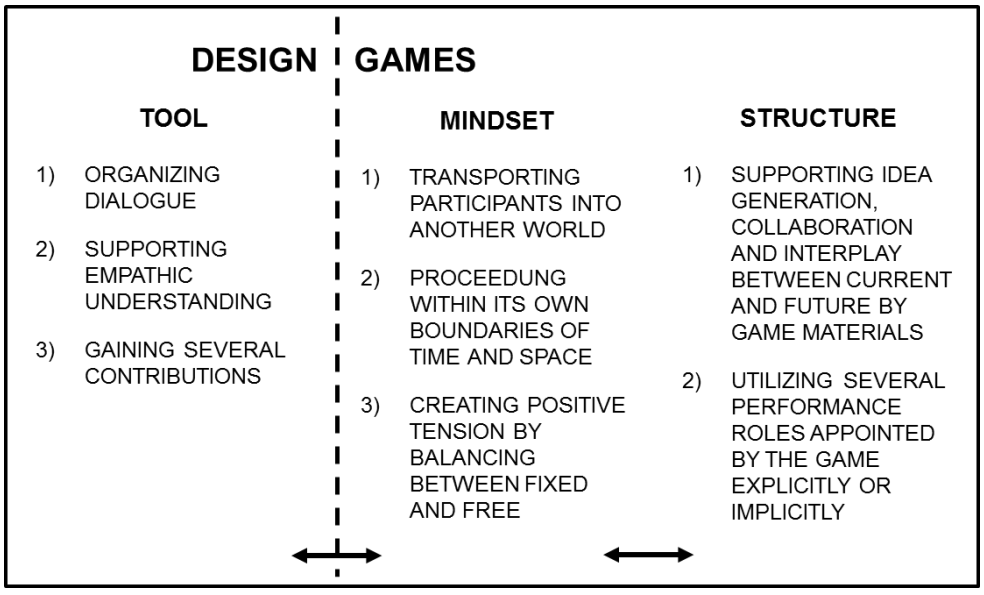

Figure 9 – Play framework, adapted from Vaajakallio (2012)

Figure 9 describes the key features of design games identified by Vaajakallio (2012) divided into three themes: design games as a tool, a mindset and a structure. As a tool for the designer, design games help the designer gather empathic understanding from multiple participants in an organized fashion. As a mindset, the game enables participants of the design process to take the role of players that transports them to

another world where time and space proceeds according to the needs of the game and creates positive limitations. As a structure for the design activity, design games provide support idea generation and collaboration while providing a platform for setting explicit or implicit roles for the players.

Vaajakallio (2012) groups the themes of mindset and structure into a larger category of "games": while the tool theme describes the utility of design games from the point of view of the designer looking to involve participants in design, the mindset and the structure themes describe how games support and guide interaction in the game context. The mindset and structure themes define how design games influence the interaction between the players, while the tool theme describes the utility a designer gains from using game structure in participative design.

Even though one of the themes is named "structure", this thesis interprets the themes of mindset and structure as the game structure of design games. Because design games have evolved in relative separation from other serious games (Brandt and Messeter, 2004), the Play framework provides an insight into how design games utilize game structure as one domain of serious games.

5. THEORETICAL SYNTHESIS

This chapter provides answers to theoretical research questions, presents theoretical models based on the theoretical framework and presents research questions for empirical study.

First, the three research questions described in Chapter 1 are answered in detail and theoretical models are presented (5.1). Second, research questions for the empirical study of this thesis are presented (5.2).

5.1. ANSWERS TO THEORETICAL RESEARCH QUESTIONS

Three theoretical research questions were presented in Chapter 1 for the theoretical review. In this subchapter, the contents of Chapters 2, 3 and 4 are summarized and developed to answer the theoretical research questions.

TRQ1: How does knowledge co-creation take place?

Knowledge co-creation takes place through the collaborative development of shared objects in a group that aims to develop their practices. Multiple theories contributing to knowledge co-creation that are analyzed in detail in earlier chapters are summarized in Table 4.

Table 4 summarizes the central theories of knowledge co-creation used in this study. While the source of new knowledge identified in each theory varies from communities developing their own practices by collaboratively creating improved solutions (Bereiter, 2002; Engeström et al., 1999; Paavola et al., 2004) to converting knowledge between tacit and explicit (Nonaka and Takeuchi, 1995) or between knowledge communities (Carlile, 2004, 2002), all theories focus on knowledge co-creation on group-level with different emphases. All theories agree that knowledge co-creation is mediated by artefacts that are created (Bereiter, 2002; Nonaka and Takeuchi, 1995), developed (Paavola et al., 2004) or used to communicate (Carlile, 2004, 2002; Engeström et al., 1999) in knowledge co-creation.

Table 4 – Theories of knowledge co-creation as an artefact-mediated social process

	Source of new knowledge	Scale of participation	Role of artefacts
Knowledge creation spiral (Nonaka and Takeuchi, 1995)	Conversion from tacit to explicit knowledge	Organization	Artefacts are created in explicitation of knowledge
Expansive learning (Engeström et al., 1999)	Questioning existing practices	Group	Artefacts are used in communicating
Knowledge building (Bereiter, 2002)	Creation and application of conceptual artefacts	Group	Conceptual artefacts are used as a tool in knowledge building
Knowledge transformation (Carlile, 2004, 2002)	Transforming knowledge from one community to another	Individuals from different communities	Artefacts that hold meaning in multiple contexts are used to translate and transform knowledge
Trialogical learning (Paavola et al., 2004)	Collaborative development of shared artifacts	Individuals in a group	Developing the shared artefacts is the objective or collaboration

In this thesis, knowledge co-creation is viewed as an artefact-mediated social process of developing the existing practices of a community. Knowledge co-creation follows three progressively more complex levels of knowledge creation. For the purposes of this thesis, these levels are referred to as the monological, dialogical and trialogical levels as described by Paavola et al. (2004) and informed by other theories (Bereiter, 2002; Carlile, 2004). The monological level is characterized by one-directional communication where individuals seek to assimilate information from their surroundings. On the dialogical level, people share knowledge and translate it to and from other contexts. On the trialogical level, groups of people from diverse knowledge backgrounds engage in collaborative effort to develop shared objects to create new knowledge in the form of solutions or models. Communities partaking in trialogical knowledge co-creation are innovative knowledge communities.

TRQ2: What are the central elements for supporting knowledge co-creation?

For the purposes of this thesis, the central elements for supporting knowledge co-creation are the objects of collaboration. Because knowledge co-creation is artefact-mediated, as previously established, the objects of collaboration shape the nature and results of the collaboration. The same objects or artefacts can be given different roles depending on the phase of the collaboration, and objects in different roles provide different support for knowledge co-creation.

According to Nicolini et al. (2012), primary objects are the objects of collaboration that motivate the collaboration and provide a shared sense of identity to the collaborators. Secondary objects are the objects which share meaning across knowledge boundaries and which are used to translate knowledge. Secondary objects can also be developed in the knowledge co-creation process to communicate and co-develop ideas and concepts into new knowledge. Tertiary objects make collaboration possible as physical tools or mediators of knowledge, but are not the conscious objects of knowledge co-creation for the collaborators.

Based on the theoretical review, a model for analyzing different levels of knowledge co-creation is presented in Table 5. The model is mainly based on the theories presented by Carlile (2004, 2002), Paavola et al. (2004) and Nicolini et al. (2012) in Chapters 2 and 3.

Table 5 – Three levels of knowledge creation in collaboration

Level	Carlile (2002, 2004)	Paavola et al. (2004)	Nicolini et al. (2012)	Theoretical objects
1	Transferring	Monological learning	Tertiary objects	Material infrastructure (Orlikowski, 2007; Star and Ruhleder, 1996)
2	Translating	Dialogical learning	Secondary objects	Boundary objects (Carlile, 2004, 2002), trialogical objects (Paavola et al., 2004)
3	Transforming	Trialogical learning	Primary objects	Trialogical objects (Paavola et al., 2004), epistemic objects (Knorr Cetina, 1997), activity objects (Engeström, 1987)

While all levels of knowledge co-creation are mediated by objects of collaboration, different types of interaction in different levels is supported by a different level of object (Table 5). Each level of knowledge co-creation is theoretically described to correspond with a level of objects of collaboration and the theoretical objects associated on the level. The ability of objects to support knowledge co-creation in a certain role is always dependent on the role the collaborators give them, and individual objects can take multiple roles over the course of the knowledge co-creation process (Nicolini et al., 2012).

The knowledge acquisition oriented level 1 knowledge co-creation is supported by material infrastructure that enables collaboration by providing the material support for allowing the collaboration to take place. Level 2 knowledge co-creation is supported by shared boundary objects that allow for translating knowledge across different contexts, or shared trialogical objects that are developed while pursuing some other shared objective. Level 3 knowledge co-creation is supported by objects that motivate the collaboration and form the shared objective of the collaboration. Such objects may be epistemic objects that represent the unknown or uncertain and the pursuit of which drives the knowledge co-creation, or activity objects that are the shared object of activities within the collaboration regardless of the goals of individual collaborators. A trialogical object can also be the shared objective of knowledge co-creation, where reaching the developed version of the trialogical object itself is the motivation of collaboration and development forms the main activity of knowledge co-creation.

TRQ3: How can games support knowledge co-creation?

Games support knowledge co-creation through providing a structure for interaction within game structure. According to the theoretical framework, game structure is defined as a system of practices, objects, and artifacts that enable game-like interaction between a game and its players, but also between the players themselves. Games are defined as “undertaking voluntary challenges that result in quantifiable outcomes” which means a game has to present goals, enforce unnecessary limits on pursuing the goals, provide feedback for the players and be voluntary to participate in (McGonigal, 2011; Salen and Zimmerman, 2004).

Games used for purposes other than entertainment form the category of serious games (Abt, 1987). In knowledge co-creation, games act as scaffolding, providing

players a space where they can perform actions they could not in ordinary life by guiding the players in the right direction and creating a space for experimentation (Vygotsky, 1978). Game material can support knowledge co-creation by providing a place where knowledge is externalized in writing or by rearranging game material (Hakkarainen, 2009). The engagement of games arises from continuous learning and progression, which makes well-designed games a promising format for learning and co-creating knowledge.

In design games, the game structure provides players with the opportunity to be transported into another world, proceed in the game's internal space and time and creating a positive tension between fixed and free (Vaajakallio, 2012). Designers of design games use the game structure to support idea generation, collaboration and interplay using game material, and utilizing the game to assign roles for players (Brandt and Messeter, 2004; Vaajakallio, 2012).

Using the model of activity systems put forward by Engeström (1987), game structure can be modeled as an object-oriented activity system. Engeström's activity system was presented in the theoretical framework, Figure 7 in Subchapter 3.1, based on which Figure 10 is presented below. Figure 10 presents a model for viewing generic multiplayer games as activity systems and the model is described in detail below.

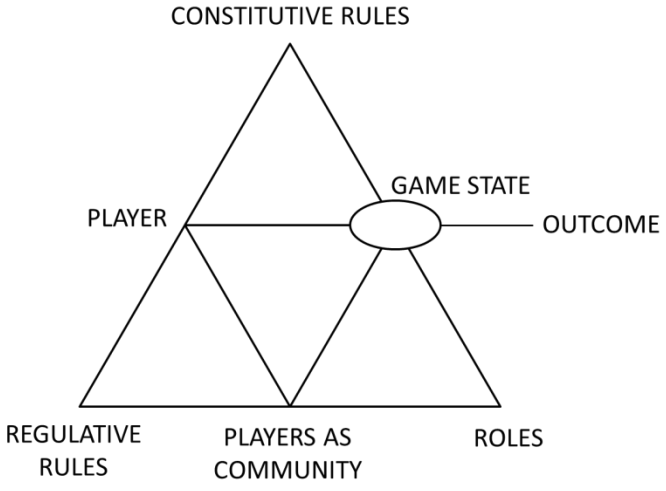

Figure 10 – Game structure as an activity system

Engeström (1987) presented the activity system in Figure 7 in Chapter 4 as a model of sense-making in the context of all human activity. Conversely, game structure is

presented in Figure 10 as a reading of games in general as an activity system. This is achieved by mapping the interaction between the players and the game.

In Figure 7 the top triangle forms the core of the activity: a subject interacting with the object mediated by tools to reach a goal. Similarly in Figure 10 the core of the activity system is consists of the player (subject) interacting with the game states of the game (object) as made possible by the constitutive rules (tools) to ultimately reach an outcome which may be positive or negative for that particular player.

The game state is defined in this thesis as the position in the gameplay that has been reached from the starting position regarding the game material, score, situation and other game metrics. A more restricted definition of game states could include only the quantifiable elements of the game, such as the position of game material or the data held by a computer running a game (Björk and Holopainen, 2005) but such definition would rule out intangible game states from the model. Therefore, for the purposes of this thesis, game state does not have to be tangible or repeatable as many game forms are the result of intense personal interaction that cannot be reduced to quantified state. This definition also allows the analysis of ideas and other epistemic elements as a part of the game structure.

In order to pursue the objective of a game, a player interacts with the game using constitutive rules that allow the player to affect the game. To quote game designer D. Vincent Baker: “The tool is not the objective. In a well-designed game, the goal can be reached by applying the tools but reaching them is not a given.” Players select and apply constitutive rules as tools to reach their goals in the game, but the tools are not used separate of the game but instead used to interact with a shared object of activity. Separating the goal of the game, i.e. the desired outcome, from the object of activity allows for analysis of the player’s goals and what the player actually does with the tools to reach his goals.

The three components on the bottom of the big triangle in Figure 7 represent the wider context in activity systems: rules and norms that bound actions, community at large and the division of labor within the community. In Figure 10 these are interpreted as regulative rules, players as community and roles.

In game structure, the empowering constitutive rules are contrasted by the regulative rules, which set limits on how existing capabilities are used (Montola, 2012).

Regulative rules are one of the four feature that defines game structure, the unnecessary limitations put upon the players by the game (McGonigal, 2011). While regulative rules limit certain capabilities, they also foster creativity. In design games, the regulative rules set by the game are used to create a creative tension between free and fixed (Vaajakallio, 2012). Regulative rules as a whole are formed out of multiple layers of rules, the most obvious ones being the explicit rules of the game being played, but regulative rules also contain wider social rules and norms.

In all multiplayer games players form a community of relationships within the game structure. A player's relationship to other players can be collaborative, cooperative or competitive, and analysis of optimal strategies often involves the strategies other players will play (Zagal et al., 2006). The relationship towards other players is always conditional on the current game state and past experiences between the players. Games that aim to create a collaborative game need to address how the players act as a community and how the players are encouraged to collaborate (Manninen and Korva, 2005; Reuter et al., 2012).

As the final component, the division of labor is represented as the player roles which can be explicitly or implicitly assigned and have a varying effect on the play depending on the game. Implicit roles will also arise from the personal interaction as players take roles in regard of the other players. Explicit roles defined by the game may but does not necessary imply that different constitutive and regulative rules apply to different players. Design games utilize the ability to assign explicit or implicit roles to encourage empathic thinking in the design process (Vaajakallio, 2012).

5.2. EMPIRICAL RESEARCH QUESTIONS

The theoretical framework of this thesis has provided answers on how knowledge co-creation takes place, what the central elements for supporting knowledge co-creation are and how games can support knowledge co-creation. Based on the theoretical synthesis, two research questions are presented for the empirical study in order to answer the research problem of this study. The refined empirical research questions (ERQ) for the study are:

ERQ1: How are different objects of collaboration formed and used within the structure of a game?

ERQ2: How does game structure facilitate knowledge co-creation as a process?

The aim of answering ERQ 1 is to analyze whether objects of collaboration can be observed within game structure in the empirical analysis and observe how different levels of objects are formed and used in game structure. The aim of ERQ 2 is to analyze knowledge co-creation using the theoretical model of game structure and how the game structure itself supports knowledge co-creation in the empirical analysis.

The research questions presented here are used in the empirical study of this thesis, and used as sub questions for answering the research problem.

III EMPIRICAL STUDY

This section describes the empirical study of this thesis. First, the research context and contents of the study are described and the two cases of the study are outlined. Second, the data collection and analysis are presented along with the key analysis methods and their application. Finally, empirical findings of the study are presented as empirically formed models.

6. EMPIRICAL STUDY DESCRIPTION

The empirical data of this study is collected from two one-day test-play events conducted as a part of ATLAS research project in Aalto University. Each event consisted of a briefing, playing the ALTAS game and a debriefing. The events were conducted in different situations with different locations, participants and surrounding organizations. The events are analyzed as two separate cases describing the use of the same game for the purposes of this empirical study.

First, the context and the background of the ATLAS game and the test-play events are discussed (6.1). Second, a description of the ATLAS game is given on a general level (6.2). The differences between the cases are described in their own subchapters (6.3 and 6.4). Finally, the results are discussed and the two cases compared (6.5).

6.1. RESEARCH CONTEXT

The two cases described in the study were part of ATLAS – a map for future service co-development research project (2012-2014). The research project aimed to develop the theory of service co-development methods by analyzing the methods used in 13 prior research projects as platform projects. The project was organized in collaboration with companies and multidisciplinary research groups. The three collaborating research groups were:

- Enterprise Simulation Laboratory SimLab, Aalto University School of Science, Department of Industrial Engineering and Management
- ENCORE research group, Aalto University School of Art, Design and Architecture, Department of Design
- IRIS research group, Aalto University School of Science, Department of Industrial Engineering and Management, BIT Research Centre

The research project consisted of five consequent sprints of approximately half a year of the project's two and a half year duration. Each sprint culminated in a Sprint day where the results of the sprint were presented to a steering group consisting of partner representatives from the partners of the platform projects. Sprint days were also used by the researchers as a chance to test the ATLAS game with practitioners to assess how the players would use the game and gather feedback form the players.

6.2. THE ATLAS GAME

The ATLAS game is a collaborative board game intended to be played in a group of three to seven players from different backgrounds and two researcher facilitators who guide the players through the game. During the game the players collaboratively answer questions that the game provides to form a project plan for co-designing a service in a predetermined case context to reach objectives they decided at the beginning of the game. The game has no single winner but the resulting project plan will reflect the performance of the players during the game. The version of the game used in the two cases of this study was a prototype intended for refining the game through testing and suggestions.

The ATLAS game was designed as a part of the research project to function as a map of different service co-development methods from different theoretical roots such as design, healthcare services and learning sciences. Within ATLAS research project the game was intended to act as a method of disseminating information and developing competences regarding service co-development methods, to practitioners and researchers alike.

The aim of creating the game was that by playing the ATLAS game the players would be able to build knowledge and capabilities for service co-development project planning and execution, to choose the suitable service co-development method(s) for the case in question, and to better understand existing services and to develop them further. During the game the players would develop their understanding of the service they were developing, of service co-development methods and ways of enabling stakeholder participation, and how each choice regarding these methods would affect the other choices and the project as a whole. At the end of the game the players would review the decisions they had made during the game, and form a shared understanding of the project they had designed in the game.

The material game pieces used in the ATLAS game are described in Table 6.

Table 6 – List of game pieces

Game piece	Form	Role
Game board	A large paper map depicting three islands and the Harbor of Change	Locations and available routes within the game
Map location markers	Round wooden chips	Determines the type of card drawn at each location
Player figures	Plastic toy figures	Marking the players' locations on the game board
Travel ticket	Sheet with spaces for text	Used to write down the objectives and the characters
Backpack	Paper sheet with space to write on for each island explored	Writing down the discussion and take-aways during the game
Objective cards	Blue hexagonal cards with text	Options from which the players choose the objectives for the service developed
Question cards	Rectangle cards with text, the cards are in three colors for the three islands: purple for Project Definition, red for Methods and Tools and green for Participants	Provide questions the players have to answer in order to develop the service
Mystery cards	Blue rectangle cards with text	Provide practical hints or surprise setbacks
Method cards	Yellow rectangle cards with pictures	Providing the players with example service co-development methods
Participant cards	Playing cards depicting family members around different professions	Providing the players with example participants
Dice	Plain six-sided die numbered from 1 to 6	A single die roll determines the number of moves a player is allowed to take during a turn
Sticky notes	Adhesive pieces of paper	Space for player notes (In case 2 the notes were attached to answered Question cards)

According to the rules of the ATLAS game, the game board is laid on a table before the game starts and the cards are placed in separate decks around the game board. The game players are seated around the game board so that they can reach all the game material.

The game consists of five consequent steps:

1. Presenting a case
2. Choosing characters
3. Selecting objectives
4. Developing a service co-development project by exploring the game board and drawing Question cards
5. Reviewing the results

At the beginning of the game the players are presented with a prewritten case that may vary – both of the test-plays presented in this study have different cases. The case in the game details a fictional location like a city or municipality facing multiple challenges ranging from decline in industry to elderly care, immigration and infrastructure. The case will also give the players some criteria on how to approach the solution: in both of the cases presented in this study the case tasked the players with developing the services in the city or municipality to a more citizen-oriented direction by involving different stakeholders.

After being presented with the case, the players choose the characters that will represent them on the game board. The character models are chosen from a number of available Playmobil® models. A total of three models are chosen and if there are more than three players all the characters are shared between players. Each character is described as a member of a project team that is developing the service the players will plan over the course of the game. Once all players are content with the characters, the players move on to select their objectives.

After choosing the characters, the players are presented with seven different objectives from which they will choose one or two to act as the objectives of the project they will plan within the game.

The available objectives are:

- Gathering new ideas
- Making an experiment
- Making an organizational change
- Bringing different parties together
- Changing organization culture into more customer-oriented
- Promoting wellbeing / social sustainability
- Other unplanned or tacit goals

The players choose which objectives they will pursue during the game. If they choose to have more than one objective, they will choose the main objective of the project from the chosen objectives. The objective cards they choose are left on the table face-up and the rest are taken aside.

Once the players have chosen the characters and the objectives, the players place their characters on the game board in the Harbor of Change. The game board is presented in Figure 11 that depicts the Harbor of Change the players start in and the three islands they explore.

Figure 11 – The ATLAS game board

The game is played in turns and the game play proceeds with every player taking a turn in sequence. At the start of each turn, the player whose turn it is rolls a die and moves a figure on the game board along paths drawn on the game board the number of steps indicated by the die roll (Figure 11). If a figure stops in a location that has not been visited earlier, the player turns the map location marker in that location over and based on the backside of the marker, takes a Question card or a Mystery card. If a Question card is drawn, the question on the card is discussed among the players and the facilitators guides the discussion if needed. During the discussion a facilitator will act as a scribe and write down decisions the players make about the service they are developing. Once the players are satisfied with their answer the turn progresses clockwise.

When moving on the game board, the aim of the players is to explore the islands as much as possible and gather a combination of questions and answers that will help them form a project plan. Even though the players make their personal rolls and decide where to move a character, all players share the same goal of planning a project and all questions are answered in consensus between the players.

After the game time allocated for exploring the islands has run out or the players decide they have gathered enough information, the players end the exploring part of the game and move to review their results. In Case 1, the review consisted of discussing what the players had found out during their game with others who had been in the same session but playing at a different table. In Case 2, the review was expanded into an implementation phase where the players sketched a project plan onto a flipchart and presented the project plan for the player team at the other table.

The ATLAS game is facilitated by two designated facilitators who are researchers involved in the development of the game. Their role is to facilitate the gameplay by asking questions and managing conflicts between the players, but they also act as game masters by explaining the game rules and guiding the players through each step of the game. As game masters the facilitators can supplement the information on the materials e.g., elaborate on the service co-development methods presented on the Method cards.

In the play-troughs of the two cases of this study, a “super game master” supervised all the groups and checked that every group was aware of how much time they had left so that the facilitators could adjust the gameplay accordingly. The super game

master could also be called if there was confusion about interpreting the rules but the super game master did not have a role within the gameplay unlike the facilitators.

6.3. DESCRIPTION OF CASE 1

The first case of the study was the initial test-playing of the ATLAS game at the Sprint day in March 2013. The event was organized by researchers at Aalto University.

The participants of the first event were representatives of organizations that were partners of the ATLAS research project with previous interest and experience in service co-development. The ATLAS game was intended to be ultimately used in private and public organizations in cross-organizational projects, so the collection of organizations partnered with the ATLAS project were considered to be suitable for testing the game. The participating organizations included multiple public and private organizations from sectors such as insurance, public transportation, innovation services, social services and health care in addition to service researchers from Aalto University that did not participate in the ATLAS research project.

The event consisted of three concurrent games played in the same room on different sets of game materials on different tables over two hours. Two tables were organized each with five external participants and two facilitators with a third table consisting entirely of researchers of whom eight played the game and two acted as facilitators. Each table had video cameras that recorded the game play for research purposes. The tables with external players played the game in Finnish and the researcher table played the game in English. All tables used identical English language game material.

Out of the three tables, table number two was selected for further study in this case because it had the most game play time out of the three tables. The table had five external players (n=5) and two facilitators (n=2). The players had not been pre-designated for any table but instead took a seat from either table freely. The players in table two were from public organizations such as municipalities and ministries (players 1, 2, 3, 5) with one external service innovation researcher (player 4).

Table one, which also had external players but was not selected for further analysis, ended their game earlier to give feedback about the game so far, and discuss how they would be able to use it in their work. The researcher table focused heavily on

analyzing the game material and questions and also spent less time on playing the game. In contrast to table one and the researcher table, table two provided the best picture for how the gameplay would look like if the game was played with completely new players in a cross-disciplinary context. An illustration of the game setup on table two is presented in Figure 12.

Figure 12 – Illustration of Case 1 set-up

Before the game the players were presented with a prepared case description that provided them with a common understanding of a project context they would be co-developing services for, including the strengths and weaknesses of the service context. The case description used in case 1 was the fictional Finnish coastal city of Stormsö. The city of Stormsö had a profile as a coastal community with local industry in fishing and smoking the local fish and a local delicacy in spoon bread. However, the city had lost a major employer since a local factory had moved offshore. Furthermore, the city organization had a reputation as being too close-minded. The players were tasked with envisioning a bright future for the city of Stormsö by concepting attractive new services and ways of engaging stakeholders that the city could use.

The initial test-playing event was the first time the ATLAS game was played with any group beyond the research group and the rules were used as presented in the previous subchapter. The game mechanics were familiar to the players from popular map-based board games, including having to roll a four or higher on a die in order to

move from one island to another through a blue dotted line called a sea route (Figure 11).

While playing the game, the facilitators in each table acted as scribes, writing on a Backpack sheet the key decisions and insights from each Question card the players answered to. After the game was over, each table presented to the whole audience what they had discussed over the course of the game and how they would use the game in their own work.

6.4. DESCRIPTION OF CASE 2

The second case of this study was the second test-play event of the ATLAS game in April 2013. The event was organized by researchers at the case company's premises.

In the second event, the participants were members of the same organization but with different roles and from different teams. Two games were played concurrently in the same space on different sets of game materials. Table one contained two employees, one junior employee and two facilitators form ATLAS research project. Table two contained three employees and two facilitators form ATLAS research project, including the author of this thesis. Each table had video cameras that recorded the game play for further research. All tables played in Finnish with English language game material.

Gameplay in the two tables was very similar with tables playing through each phase of the game in the same allocated timeslot and prepared a similar project plan draft at the end of the game. Only one table was chosen for further analysis in this thesis because the game was used in equivalent ways. Because the author was present in table two, table one was selected in order to separate the observations made by the author in the analysis from the observations made during the game. An illustration of the table one set-up is presented in Figure 13.

Figure 13 – Illustration of Case 2 set-up

After the game had been initially tested with outside audience as described in Case 1, some minor adjustments were made to the rules of the game. The movement rules were adjusted so that the blue dotted line sea routes no longer needed a successful die roll to cross, and it was emphasized that the player could stop at any point in their movement to land on an unvisited location of their choice. The duties of writing down the answers to each Question card was delegated from the facilitators to the players: the answers to each card were written down by the players on a sticky note, attached to the drawn Question card and placed on the table so that all players could see the questions and answers.

Before the game began, the players were presented with a prepared case description like on the Sprint day. The case description used in Case 2 described the city of Kaarlehamn, a Nordic coastal city at the distance of 50 km from the capital of another Nordic country. The case description listed multiple areas that the city had identified as potential areas of development, including infrastructure, elderly care, education and immigrant integration. The players were tasked with developing concepts that would empower the citizens of the city by participating in developing the new services the city would develop.

During the game, the players themselves were responsible for writing down the discussion regarding each card on a sticky note and attaching it to the card in question. As the game progressed, each team gathered a collection of questions and

answers that contained the cumulative discussion regarding the project they were planning.

After the game was over, each team formed a project plan outline according to the discussion they had had during the game. Each team presented their own project plan to the other players and researchers. The players also discussed how they would use the game in their work.

7. DATA COLLECTION AND ANALYSIS

This Chapter examines the role of game structure in knowledge co-creation through empirical analysis. First, the data collection and analysis methods used in the study are presented (7.1). Secondly, the collected data from the two cases is described (7.2 and 7.3). The data is presented using excerpts, video frames and structural logs on a turn-by-turn structure to illustrate how the game progressed in each case.

7.1. RESEARCH METHODOLOGY

The method for data gathering in this study was video recording. Both of the events described in Chapter 6 were set up specifically for presenting the ATLAS game to the partner organizations, and testing the ATLAS game for its future development. The participants of the events knew in advance that they would be playing a prototype, and would be asked to give feedback and suggestions for developing the game, and that the playing would be recorded for research use.

The author of this thesis was present at both events: as an external observer at the Sprint day gameplay (Case 1) and as a facilitator in one of the tables at the consulting company (Case 2). The data for the empirical study was selected so that the author does not appear in either of the videotapes to separate observations made during the events from those made in analyzing the video data.

Each game event was videotaped using a single fixed point video camera set up so that the table, game material and players playing the game that was being videotaped would be as clearly visible as possible. A separate audio recorder was set on each table in order to record an additional audio track for each video.

The analysis was done using ATLAS.ti 7 software (no affiliation with ATLAS research project) which was used to watch the video recordings and make notes to the recording and transcripts. Analyzing the videos was started with watching all tapes from all tables in both cases, altogether five videos. One table from each case was selected for further analysis. In Case 1, the table was selected since it was the only table which consisted of external players and got to play the whole allocated game time without distractions. In Case 2 both tables were very similar so only one was chosen for empirical analysis. The table which did not feature the author of this

thesis was selected based on the notion that analysis should also be done by external researchers if possible.

The selected videos in both cases were analyzed in three phases as outlined in Subchapter 1.3. The three phases presented by Heath et al. (Heath et al., 2010) are:

1. The preliminary review, which consists of looking through the data and establishing a content log to outline how relevant segments are arranged in the data.
2. The substantive review, in which the content log written during the preliminary view is used to investigate data more closely and classify sections based on the observed phenomena.
3. The analytic review, in which segments identified as important in the substantive review are analyzed and classified in detail.

Each phase included watching the video multiple times, and iteratively developing the analytical observations and the theoretical framework according to the abductive research approach used in this thesis.

First, in the preliminary review, the videos were catalogued as content logs describing the phases of each video and the length of each phase. Content logs for each case are presented in Subchapters 7.2 and 7.3.

Second, in the substantive review, each video was divided into consequent turns which were numbered and listed as turn logs in order to get a picture on how the game played over the course of one session and how the co-created knowledge accumulated over time. For each turn or equivalent episode, the cards drawn and what the players answered as a group to the question was written down into turn logs. Because of the length and scope of turn-by-turn analysis, the turn logs are presented in Appendix I and Appendix II of this thesis.

Third, in the analytical review, three individual turns per video were selected as fragments for speech act level analysis. The fragments were transcribed for the analytical review at a speech act level from audio and video data to document the verbal and non-verbal interaction between the participants and game material. The transcriptions were then used to analyze the knowledge co-creation process and the effect the game had on it. All transcribing was done word-for-word in Finnish, and the transcriptions were translated to English by the author only for the parts that are

used in this thesis. The turn logs of the fragments selected for analytical review are presented in Subchapters 7.2 and 7.3.

Figure 14 illustrates the process of analyzing the video data. From left to right the user interface shows 1) the complete set of codes used 2) the fragment transcript with red text-to-video synchronization points 3) the list of codes connected with quotes and 4) the video data.

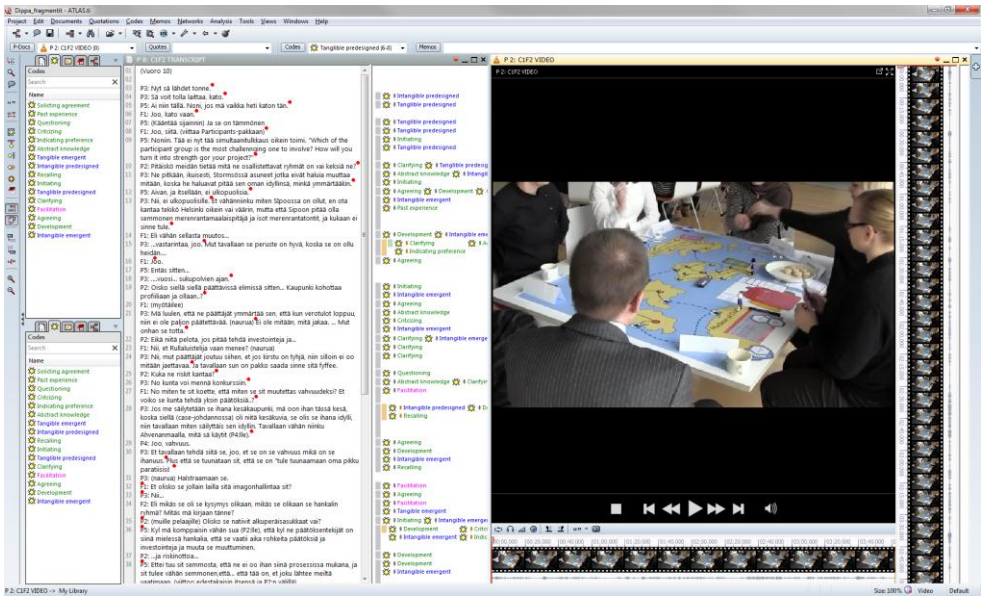

Figure 14 – Illustration of using Atlas.ti for interaction analysis

The analytical review included comparison between empirical observations and theoretical framework. The theoretical concepts used in the analysis have been introduced in the Theoretical framework part of this thesis (part II). Table 7 describes preliminary codes for operationalizing the central concepts of the theoretical framework of this study. The table includes extracts from the two cases to demonstrate how the concepts were used in the empirical study.

Table 7 – Preliminary speech act level operationalization

Code category	Speech act code	Definition	Example from data
Knowledge co-creation	Initiating	Presenting an answer for discussion	"What about the Factory-owner?"
	Indicating preference	Expressing an opinion without direct connection to new evidence or examples	"I'd go with the Farmer."
	Questioning	Asking for further clarification or explanation	"The Lieutenant's wife… I wonder if the military's that strongly present here."
	Agreeing	Indicating agreement	"Yeah."
	Criticizing	Pointing out flaws or contradictions	"It's not really proactive change if we have already waited until the factory has moved out of the country."
	Sharing abstract knowledge	Presenting previous knowledge without examples	"People like Mrs. Vigorous are needed in these kinds of processes."
	Sharing concrete knowledge	Presenting previous experience and drawing parallels	"Like in the Design Capital project you were in, the city also made proactive change there since the city could have continued as they were."
	Recalling	Referring to an earlier discussion or an established fact within the game	"And the better life [objective] comes from the ground, the rationality."
	Soliciting agreement	Asking a player or players to agree on a decision or piece on knowledge	"This could be it, couldn't it?"
	Developing	Building on top of a previous statement and implicitly agreeing with it	"Yeah, regionalism (picks up a card), and this would kind of support and balance it out."

Objects of collaboration	Material infrastructure	Interacting with the game without promoting knowledge creation	Dealing cards from a deck, moving tokens
	Boundary object	Making a verbal of physical reference to a shared object within the game to anchor discussion	"Could this Electricity person represent the energy industry?"
	Trialogical object	Deliberately developing a shared object to create knowledge	"And their [Farmer and Factory-owner] dialogue would be easier to communicate to the target audience because of how they represent opposite views…"
	Activity object	A shared object of collaboration acts as the motive for collaboration	"So which of the groups is the most challenging to engage?"
	Epistemic object	A desire to know more about an object acts as the motivation for collaboration	"And then we have to form a common understanding in which direction we are going to develop the municipality, so we don't end up going in different directions."

The codes were used on the speech act level of analysis, to observe knowledge co-creation processes and the use of objects. The analysis was done using Atlas.ti software by transcribing fragments at speech act level complemented with notes of physical interaction on the video. Results of the analysis and the developed set of codes are presented in Chapter 8.

7.2. CASE 1: INTER-ORGANIZATIONAL COLLABORATION

Case 1 was analyzed as described under "Research methodology" in three phases: preliminary review, substantive review and analytical review.

In the substantive review the high-level events were catalogued into a Content log, presented in Table 8. Each event has been marked with the point on the video when the event begins, the duration of the event i.e. the time between event beginnings, and the description of the event. Note that the briefing about the case context for the service development was given in a presentation for both tables together, and is not part of the video being analyzed.

Table 8 – Content log, Case 1

Time (h:min:sec)	Duration (min:sec)	Description
0:00:00	02:39	Gathering around the table and greeting other players
0:04:30	01:39	Explaining the rules and the travel backpack.
0:06:09	06:55	Selecting characters.
0:13:04	05:36	Selecting a purpose of travel.
0:18:40	00:51	Explaining the movement rules.
0:19:31	17:26	Turns 1 to 9.
0:36:57	01:59	One of the characters is moved to the Participants island to speed up the game.
0:38:56	23:02	Turns 10 to 17.
1:01:58	02:33	Time is up, last turn 18 out of sequence.
1:04:31	00:56	The game ends. All tables are instructed to present their results after the break.
1:05:27	00:17	Players leave for break. Recording ends.

In the beginning of the game, approximately one-third of the play time was used in introducing the rules, and choosing the characters and the goals for the game. Most of the game time was used in playing by the players taking turns in order. At the end of the video, the players leave the table and later return to share their experiences.

In the substantive review, a turn log was made based on the video. The turn log for the whole session is presented in Appendix I. Turns 5, 10 and 11 were selected from the case data for further analysis (Table 9). The three particular fragments were selected because they exhibited the most active discussion and knowledge co-creation, enabling analysis into what role the objects served when knowledge co-creation could be observed. The three fragments also represent the three categories of Question cards: Project Definition in turn 5 (Fragment 1), Participants in turn 10 (Fragment 2) and Methods & Tools in turn 11 (Fragment 3). Fragment 3 also serves as an example of building on the knowledge established on an earlier turn, as methods selected on turn 11 are chosen based on their fit for the participant groups identified on the previous turn, turn 10.

Table 9 – Fragment log, Case 1

Fragment	Time (h:min:sec)	Event	Card drawn/ Question	Description
1	0:22:40	Turn 5	Project definition card: *"What is the reason for change?"*	The city is reacting to conditions that have already changed, but the project aims to proactively change the municipality to a more citizen-oriented way of working.
2	0:38:56	Turn 10	Participants card: *"Which participant group is the most challenging one to involve?"*	The most difficult groups are the senior citizen and the municipality decision makers. The senior citizen will be used to convey a positive, traditional atmosphere in marketing and the decision makers will be made to invest in the changes and make hard decisions to commit them.
3	0:43:00	Turn 11	Methods and Tools card: *"In what forms will you gather participant information?"*	Video clips from the municipality filmed by potential citizen, and video data from group interview workshops that use the clips as material for discussion.

Table 9 marks the number of the fragment, the starting point of the fragment on the videotape, the length of the turn, the type and content of the card drawn on the turn and a description of what the players decided to be the answer to the question posed on the card.

7.3. CASE 2: INTRAORGANIZATIONAL COLLABORATION

Like Case 1, Case 2 was analyzed as described in Subchapter 7.1. The analysis followed three phases: preliminary review, substantive review and analytical review.

In the substantive review, the high-level events were catalogued into a Content log, presented in Table 10. Each event has been marked with the point on the video when the event begins, the duration of the event i.e. the time between event beginnings, and the description of the event. Like in Case 1, the briefing about the case context for the service development was given in a presentation for both tables together and is not part of the video being analyzed.

Table 10 – Content log, Case 2

Time (h:min:sec)	Duration (min:sec)	Description
0:00:00	02:11	Explaining the movement rules and cards.
0:02:11	03:14	Selecting characters.
0:05:25	02:11	Selecting a purpose of travel.
0:07:36	00:32	Starting the game.
0:08:08	37:00	Turns 1 to 14.
0:45:08	01:12	Super game master guides to review the material gathered during the game.
0:46:20	11:54	Turns 15 to 19.
0:58:14	03:16	Facilitator asks the players to expand the discussion about participants.
1:01:30	01:22	Facilitator tells the players to move to the Implementation phase once they feel they have enough material. The players decide to move one of the characters to the Harbor of Change to begin the Implementation phase.
1:02:52	00:46	Players go through the material they have gathered during the game and think they have the right participants and objectives to reach the project objective.
1:03:38	18:41	Players write a preliminary project plan for the project they have co-developed during the game based on the discussions they have had and the notes they have written on the sticky notes over the course of the game.
1:22:19	00:00	Game ends.

The content log shows that the rules were introduced and the characters and goals were chosen in approximately eight minutes with three players who had never played the game. Most of the game time was used by the game turns. In contrast to Case 1, Case 2 was set up so that the players in both tables had an extended period of time at the end of the game (from 1:03:38 to the end at 1:22:19) for the players in both tables to go through the results of their gameplay and create a short description of the project plan they had developed during the game.

In the substantive review, a Turn log was made based on the video. The turn log for the whole session is presented in Appendix 2. Turns 7, 11 and 15 were selected from the case data for further analysis (Table 11). The three particular fragments were selected based on the same criteria as in Case 1: they exhibited the most active

discussion and knowledge co-creation, enabling analysis into what role the objects served when knowledge co-creation could be observed.

Table 11 – Fragment log, Case 2

Fragment	Time (h:min:sec)	Event	Card drawn/ Question	Description
1	0:15:57	Turn 7	Participants card: "*Take 5 participants cards, choose 1- 2 most important to involve.*"	The players choose to involve a factory owner for commercial a viewpoint and financing and a farmer for communal, ecological and earthly viewpoints. The two are seen as polar opposites balancing each other. The concept of better life is developed by connecting it to earthiness.
2	0:33:19	Turn 11	Participants card: "*How do you want the participants to participate? Source of information, co-developers or both?*"	The players identify that having the participants as co-developers would be ideal and connects with the case aim. The players note that groups and associations are easier to involve than individual middle-aged citizen.
3	0:46:20	Turn 15	Project Definition card: "*What is the reason for change?*"	The players recall that the case mentioned many undergoing initiatives in the city but they had not had any real effects yet. The players decide that the project they are developing aims to make a concrete change where the other initiatives have not.

Like in the Fragment log of Case 1 in Table 9, the Fragment log in Table 11 marks the number of the fragment, the starting point of the fragment on the videotape, the length of the turn, the type and content of the card drawn on the turn, and a description of what the players decided to be the answer to the question posed on the card.

8. EMPIRICAL FINDINGS

The empirical analysis aimed at making observations from the data that would help answer the research problem: *"How do game structures support knowledge co-creation?"*. This chapter details the results of the empirical analysis described in Chapters 6 and 7.

The results have been divided into two categories: game structure as a platform for collaboration (8.1), and game structure as a trigger for knowledge co-creation (8.2). Each of the categories provides answer to an empirical research question. The observations are presented with excerpts from the data used in the analytical review, the third and final phase of analysis, as described in chapter 7. The empirical observations made in this chapter are used in Chapter 9 to answer the redefined research questions.

8.1. FORMING AND USING OBJECTS OF COLLABORATION

The empirical research question 1 was "How are different objects of collaboration formed and used within the structure of a game?". This subchapter presents the findings of the empirical analysis to answer the empirical research question.

The ATLAS game was played by the players in two different contexts in the two cases, and the observations made in the two cases were mostly in line with each other except for certain points which have been noted in the text. In the analytical review of this study, the chosen fragments of each case were analyzed based on the codes presented in Chapter 7. However, during the analytical review it was observed that the theoretical objects could not be directly linked to the empirical data. Instead, a working version classification for the objects used in the game was inductively created.

During the game the players interacted with multiple objects that can be roughly characterized in two dimensions: tangible versus intangible, and predesigned versus emergent objects. The dimensions have been visualized in Table 12.

Table 12 – Dimensions of game objects

Tangibility dimension	Emergence dimension: Predesigned	Emergence dimension: Emergent
Tangible	Game board, cards, methods, game rules	Character figures, participants, post-it notes, Backpack sheet
Intangible	Case description	Project plan, service concept, expanded case context, personal experiences

The dimensions of Table 12 have been inducted from the empirical analysis. The tangibility dimension refers to the physical interaction between the players and the game through the manipulation of game material, in contrast to the intangible creation, manipulation and development of epistemic constructs related directly to the knowledge co-creation process. The emergence dimension refers to the use of objects that have been created prior to playing the game for use during the game in contrast to objects that the players form and use during the game. The four categories described in Table 12 are described in detail in this subchapter.

Tangible predesigned game objects were the first objects observed in the game. Tangible predesigned objects were characterized as physical artefacts that had been designed by the researchers as the physical game material such as the game board, different decks of cards. The material was used by the players to move forward in the game structure, e.g. by rolling the die, moving a figure or drawing a card. In the following excerpt, the die, the game board and the figure are all used as tangible predesigned objects as the player starts his turn by rolling the die and moving his figure accordingly:

Player: "Is it my turn?" [Player rolls the die.] "One, two, three, here? And now I get to draw a card." [Player reaches for the card deck.]

While game rules in themselves are a social construct, and therefore intangible, the game rules were embodied in and mediated by the physical game material. References to the game rules were made through the physical game material as demonstrated in the fragment above: the manipulation of game material included interacting with the shared game rules.

Many cards within the ATLAS game included descriptions and some were connected to complex epistemic constructs such as the different service co-development methods depicted in the Methods and Tools cards and the Question cards. However, like with the game rules, interaction with the knowledge referenced in the cards was mediated by the physical game material.

Tangible emergent game objects were physical objects that were predesigned, but the players created new meanings for them. The figures used in the game were designed specifically to enable players to form their own ideas about who they think should be part of the project in terms of roles and personality types. During the game, the players collaboratively created new identities for the characters and maintained the created characters consistently throughout the game when interacting with the character figure.

Another example of observed emergent tangible objects were the Participant cards. The participant cards themselves only included a profession, family role, humorous name and a cartoon picture of the participant, e.g. "Carl Salmon, The Fisherman's Son" or "Lieutenant Sabre, The Officer".

Once formed by the players, the knowledge referenced through the objects was arguably intangible, but the game material was used by the players through physical cues to reference the concept connected to the cards. This is demonstrated by the following excerpt where the facilitator and the players reference the card when discussing a participant group they had established earlier in the game:

Facilitator 1: *"But do you want these too [raises and holds visible Participant cards chosen earlier in the game] How about these, do you want them to also co-develop with you? "*

Player 3: *"Yes."*

Player 5: *"Yeah."*

Facilitator 1: *[Keeps holding the cards up]" Or are they an information source for you?"*

Player 2: *"Actually yes, do we really want our funders, over there, [refers to the cards] to give us restrictions on what we're allowed to do?"*

In both cases analyzed in this study, the answers to each Question card had to be written down but the writer was different, because of changes made to the game rules between the two events. In Case 1, one of the facilitators was in charge of writing the answer on the Backpack sheet, and the facilitator asked the players to condense their answer to a few words. In Case 2, the player who had drawn the cards was tasked with writing down the answers to the Question cards on sticky notes that were attached to the Question cards. In both cases, the condensing and explicitation

of the answer became an emergent tangible object, whether the physical component was the Backpack sheet or the sticky note.

Intangible predesigned game objects included the case context description given to the players at the beginning of the game. The case context description served as the foundation for the players to add their own experiences and to develop details to the contextual factors the service they were co-developing would take into account. The case description was designed beforehand for the game instead of being created as a part of the game, making it a predesigned object. However, in contrast to the cards used in the game, the case context description did not become a mediating physical representation in the game. In Case 1, the case context description was handed to the players on a printed sheet of paper but the players chose not to interact with the printout but instead referred to the case context description as an intangible object they shared. The following excerpt describes players referring consistently to details they had identified from the case context description:

Player 2: *"Can we still affect the change [that the factory is leaving the municipality]?"*

Player 3: *"But isn't it like, that we're thinking proactively, that we're not just replacing the cookie factory with some new herring factory or a smoker, but we're going with the Flitter [character] and the Skater [character], and yeah, the Citizen entrepreneur [character], to do all other kinds of things."*

Player 4: *"But the reason for all this change [in the municipality] was the fact that they had all this difficulty and slowness."*

Player 1: *"…there has been this change happening…"*

Player 5: *"But the society and the situation there have changed."*

Dividing the case context into individual objects, each referring to an actor or a piece of information the player could reference, suggested that the players have a plethora of different objects they can reference. However, the empirical analysis suggested that the case context description acted as a single predesigned intangible object that was designed as a single part of the game and that the players described as a single source of information. Only after the player started to expand upon the details of the

case context did the details in the case context become individual emergent objects the players used in organizing the discussion.

Emergent intangible game objects were intangible objects that the players themselves created, in contrast to the predesigned case context description. While the case context description can be characterized as a predesigned object since it was created before the game began separate from the players, emergent intangible objects included completely new concepts that did not appear anywhere in the predesigned game material. For example, the project the players were planning, the potential services the players came up and the personal experiences with services and service co-development the players all became emergent intangible objects as the players consistently referred to them. Emergent intangible objects also arose from expanding and completing the predesigned case description to find common understanding about the case context, as described in the following excerpt:

> *Player 3: "One participant group might be the people who have been living in Stormsö forever and don't want to change anything because they want to keep their own idyll, which is understandable."*
>
> *Player 4: "And for themselves, not for outsiders."*
>
> *Player 3: "Yeah, not for outsiders. Like for example in [a municipality in Southern Finland that had parts of it integrated to another municipality], I'm not taking account on what [other municipality] did there was right, but there was this idea that [the first integrated municipality] should always be this seaside rural commune with big shoreline properties and no one should come there."*

Emergent intangible objects were not tied to a physical representation on the game board but regardless provided a common line of thought from one turn to another, and the objects could be referred to in later discussion as common facts. In the previous excerpt, the anecdote of one player regarding an actual stakeholder group she had had contact with became a shared intangible object. The intangible object of "the stubborn people in [the municipality]" not only persisted in the game, but also established that there is a similar stakeholder group in the case context, once all players had accepted it.

The two dimensions of objects of collaboration provided insight into how objects were used by the players in game structure. The inducted model covered all game

pieces that were part of player collaboration. The findings regarding the forming and using game objects were consistent between the two cases, regardless of the background or number of players.

8.2. SUPPORT OF KNOWLEDGE CO-CREATION PROCESS

The empirical research question 2 was "How does game structure facilitate knowledge co-creation as a process?". This subchapter presents the findings of the empirical analysis to answer the empirical research question.

In order to evaluate the ability of game structure to support knowledge co-creation, the ATLAS game was mapped out as a process. According to the rules of the ATLAS game, described in detail in Chapter 6, the game consists of five consequent steps: 1) presenting a case, 2) choosing characters, 3) selecting objectives, 4) developing a service co-development project by exploring the game board and drawing Question cards, and 5) reviewing the final project.

Based on the empirical analysis, the ATLAS game was divided into three phases to describe it as a process. Each phase had a distinct role in supporting knowledge co-creation: orientation, gameplay, and reflection. The three phases of the game are illustrated in Table 12, where column "Gameplay phase" refers to the phases identified from empirical analysis and "Game steps" refers to the steps detailed in the rules of the ATLAS game.

Table 13 – The ATLAS game as a knowledge co-creation process

Gameplay phase	Game steps
Orientation	1. Presenting a case
	2. Choosing characters
	3. Selecting objectives
Game turns	4. Developing a service co-development project by exploring the game board and drawing Question cards
Reflection	5. Reviewing the results

The first phase, orientation, acted as a primer for the knowledge co-creation. The players were set up with a shared context for co-developing the project plan with the case context description. The players made sense of the case context and brought their own experience to the game by creating the characters that would represent

them within the game. The players were also able to think about the aim of the project by selecting objectives that would fit the case context from the available Objective cards.

The second phase, game turns, took most of the time in the ATLAS game, and the game turns can be considered the "core activity" of the game. Game turns were divided into individual turns, each of which acted as an iterative knowledge co-creation step in the ATLAS. Each turn began with a trigger for further knowledge co-creation in the form of a card. In the case of Question cards, the players were guided into planning new features of the service co-development project. In the case of Mystery cards, the players were forced to rethink their project plan as each Mystery card provided a hint or a disruption to the game.

The third phase, reflection, played a different role in each of the two cases. In Case 1, the outcome of the game was left undefined and the players briefly reviewed the discussion they had had over the course of the game. In this situation, reflection on the results or new knowledge co-created through the game was overcome by the analysis of the game mechanics. In Case 2, the outcome was more strictly defined. The players were tasked with not only reviewing their collective decisions but to develop a project plan draft that would include all identified stakeholders and the first steps towards implementing the project they had planned in the game. This provided the players with an additional chance to look for connections between the different decisions made and the choice of methods and participants they had made.

After dividing the ATLAS game as a process into a three phase process, the game turns phase was identified as the most important phase for supporting knowledge co-creation. Based on the empirical analysis, answering Question cards on game turns was the principal method of pursuing the stated objective of the game: developing a service co-development project.

In the empirical analysis, the knowledge co-creation during game turns appeared as an iterative process that started with the case context description given to the players at the very beginning of the game. The case context served as a shared background that the players would build their answers on, and the case context was extended to serve any information needs they might have over the course of the game. On each turn the players added new information to the project plan, building on top of the

initial context on each turn by collaboratively proposing and negotiating new knowledge in an effort to answer the Question cards.

Based on the inductive empirical analysis, four knowledge co-creation phases were identified within each game turn: proposing, negotiating, co-developing and explicating. The structure of the knowledge co-creation process was inducted from the empirical data using the speech act codes presented for empirical analysis in Table 7 (page 59), and the phases were cross-referenced with the use of game objects described in Subchapter 8.1. The knowledge co-creation cycle of each game turn identified in the empirical analysis is presented in Table 14.

Table 14 – Game turn knowledge co-creation steps

Knowledge co-creation phase	Speech act codes associated with the phase	Game objects associated with the phase
Proposing	Initiating	Intangible predesigned Tangible predesigned Intangible emergent
	Sharing abstract knowledge	
	Clarifying	
Negotiating	Agreeing	Tangible predesigned Intangible predesigned Intangible emergent Tangible emergent
	Criticizing	
	Questioning	
	Indicating preference	
	Sharing concrete knowledge	
Co-developing	Recalling	Intangible predesigned Intangible emergent Tangible emergent
	Developing	
Explicating	Developing	Tangible predesigned Tangible emergent Intangible emergent
	Agreeing	

As described in Table 14, the players began each turn by interacting through physical artefacts, proposing possible answers and sharing their general knowledge regarding the question in the proposing phase. Once propositions had been made, the players debated the benefits of different approaches and shared experiences that could be compared to the alternatives in question in the negotiating phase. After a common ground had been negotiated, the players began developing each other's ideas and connect the ideas to previously accepted knowledge about the case context

or the project plan in the co-developing phase. Once the co-development slowed down, the answer was negotiated into a short explicit form to write it down as an answer to the question in the explicating phase.

The findings regarding the knowledge co-creation were consistent between the two cases. However, the data form Case 2 suggested that the ideas developed by players that come from the same organizational context accept claims made by other players more easily. This resulted in more ideation being built on top of earlier statements but discussion often moved rapidly, with the players accepting the first possible idea for advancing instead of reflecting on the consequences and alternatives of the decision.

This chapter presented key findings regarding the forming and use of game objects in collaboration using two dimensions to characterize the objects: emergence and tangibility. Additionally, a cyclical process of knowledge co-creation was identified in the game turns. The type of object used did not directly correlate with the knowledge co-creation process inducted from the empirical analysis, but different types of objects were used in different phases of the game.

IV CONCLUSIONS

The preceding parts of this thesis present the theoretical framework and empirical study. This part of the thesis brings the discussion between the results of the study and the theoretical framework, the solution to the research problem, the implications and evaluation of the study, and topics for future research.

9. RESULTS

In this chapter, answers to the empirical research questions are presented and the relationship of the results of this study to the theoretical framework is discussed.

9.1. ANSWERS TO THE RESEARCH QUESTIONS

ERQ1: How are different objects of collaboration formed and used within the structure of a game?

As described in Chapter 3 (Table 5, page 38), the classification used for different objects of collaboration used in this thesis follows a division between primary, secondary and tertiary objects of collaboration (Nicolini et al., 2012). These levels of objects describe how an object of collaboration support knowledge co-creation, based on theoretical objects of material infrastructure (Orlikowski, 2007; Star and Ruhleder, 1996), boundary objects (Carlile, 2004, 2002), activity objects (Engeström, 1987) and epistemic objects (Knorr Cetina, 1997). The categories for supporting collaboration consist of motivating the collaboration (primary), translating knowledge between the collaborators (secondary) or being used to enable the collaboration (tertiary) (Nicolini et al., 2012). Additionally, trialogical objects (Paavola et al., 2004), i.e. objects that are developed during collaboration, can take the role of primary and secondary objects over the course of the collaboration.

In Chapter 8 (Table 12, page 65), a classification for game objects inducted from empirical analysis was described, dividing the objects used in the game in two dimensions: emergence and tangibility. Objects in the empirical data were observed to be a combination of either tangible or intangible, and predesigned or emergent.

When the empirical model was compared to the theoretical framework of primary, secondary and tertiary objects, key similarities were identified. A synthetic model is presented in Table 15, which combines the four categories of game objects described

in the empirical findings and the three levels of objects established in the theoretical framework. The categories of objects are discussed further below with references to the theoretical objects that comprise the three levels of objects of collaboration, found in Chapter 3.

Table 15 – The forming and use of objects of collaboration in game structure

Tangible predesigned objects	**Tangible emergent objects**
The game provides a structure for moving forward in the knowledge co-creation process Tertiary objects: *Material infrastructure*	The game material provides tangible connection points for communicating abstract ideas such as stakeholders and processes Secondary objects: *Boundary objects, Trialogical objects*
Intangible predesigned objects	**Intangible emergent objects**
The game provides a common goal for the players Primary objects: *Epistemic objects*	The players form and develop service concepts, expand case context and introduce personal experiences Primary objects: *Activity objects* Secondary objects: *Boundary objects, Trialogical objects*

According to the empirical analysis, tangible predesigned objects provided a structure for the game and a common ground for collaboration without contributing directly to knowledge creation. The tangible predesigned objects helped the players to move forward, gather focus and provide a space for collaborating. These observations are consistent with the theory of material infrastructure (Star and Ruhleder, 1996) which describes objects that are in the background of collaboration, embedded in the routines of the activity. The empirical results on the use of material infrastructure are consistent with those suggested by tertiary objects of collaboration (Nicolini et al., 2012).

Tangible emergent objects observed in the empirical analysis were shared by the players because their physical representations were visible to all players. Players came to different conclusions what, for example, the Fisherman means in the context of the particular case description, but having a shared object that triggered an association with the Fisherman enabled the players to communicate using the common point of reference. In these situations, the objects acted as boundary objects

(Carlile, 2004, 2002), occupying a meaning in multiple communities of practice which enabled the players to translate and transform their knowledge across knowledge boundaries, consistent with the theory of boundary objects (Carlile, 2004, 2002). The use of boundary objects was always initiated by the players, and objects were only classified as boundary objects through their use, not by being named by an outside actor (Levina and Vaast, 2005).

All tangible emergent objects did not function only as objects of translation and transformation. Tangible emergent objects, like the Backpack sheet and the sticky notes in Case 2, were created and developed over the course of the game, consistent with the traits of trialogical objects (Paavola et al., 2004). Collaboratively writing answers to new questions and reflecting on previous answers enabled knowledge co-creation to occur as a part of developing the objects, as with trialogical objects (Paavola et al., 2004). Both boundary objects and trialogical objects were used to support knowledge co-creation instead of motivating it, consistent with the definition of secondary objects of collaboration (Nicolini et al., 2012).

As an intangible predesigned object, the case context description given to all players at the beginning of the game provided a common backdrop of information and shared points of interest, such as the challenges the municipalities in each case were facing. According to the empirical analysis, the backdrop of the case context description provided the shared goal of finding a solution to the problems presented in the case context description. As such, the case context description was an object that provided motivation for collaboration, consistent with the description of primary objects of collaboration (Nicolini et al., 2012).

According to the empirical analysis, the case context description also provided the basis for adding new information to the case context. This description is consistent with the theory of epistemic objects as the unifying but unreachable object of desire and collaboration that drives the pursuit of new knowledge (Knorr Cetina, 1997). Even though the players did attach new information to the case context description, the full final answer to the challenges posed by the case context description remained elusive, as new Question cards asked the players to search new facets and unexplored avenues of inquiry about the case context.

The most enigmatic category of the game objects was the intangible emergent objects, which were formed and used by the players based on nothing but the

triggering game material available during the game. These objects included details and stakeholders the players identified from the case context description and developed further by combining their existing knowledge with the triggering material and the project plan the players create through answering the Question cards. Emergent intangible objects played a key part in knowledge co-creation. They acted as shared ideas, working theories and applicable experience similar to conceptual artefacts (Bereiter, 2002) or the objects of World 3, the world of ideas as opposed to the world of matter or mental states in the theories of Karl Popper (Popper and Eccles, 1984).

The intangible emergent objects took many roles during the game. First, the project plan was developed over the course of the game as an intangible trialogical object (Paavola et al., 2004), constantly developed and negotiated as new information about the context was established. However, Paavola et al. (2004) emphasize the materiality of trialogical objects including the iterative development of texts and other shared objects, whereas information about the project being planned was generally never put into explicit form. Second, the project took the role of an activity object (Engeström, 1987), as the development of the project plan constituted the main objective of the players' mental efforts and established them as collaborators with the same object. Third, some objects acted merely as boundary objects (Carlile, 2004, 2002) for translating knowledge from one context to another through examples form the players' own experiences. The experiences shared with the other players would then become embedded in the case description and accepted as true within the game.

In order to analyze the relationship between the game objects and the game structure, a contextualized version of the game structure described in Chapter 5 (Figure 10) is presented in Figure 15. The contextualized model describes the game structure of the ATLAS game by linking features of the ATLAS game to each component of the game, modelled as an activity system, as described in Chapter 5 (page 62). The model described in Figure 15 has been derived from empirical analysis.

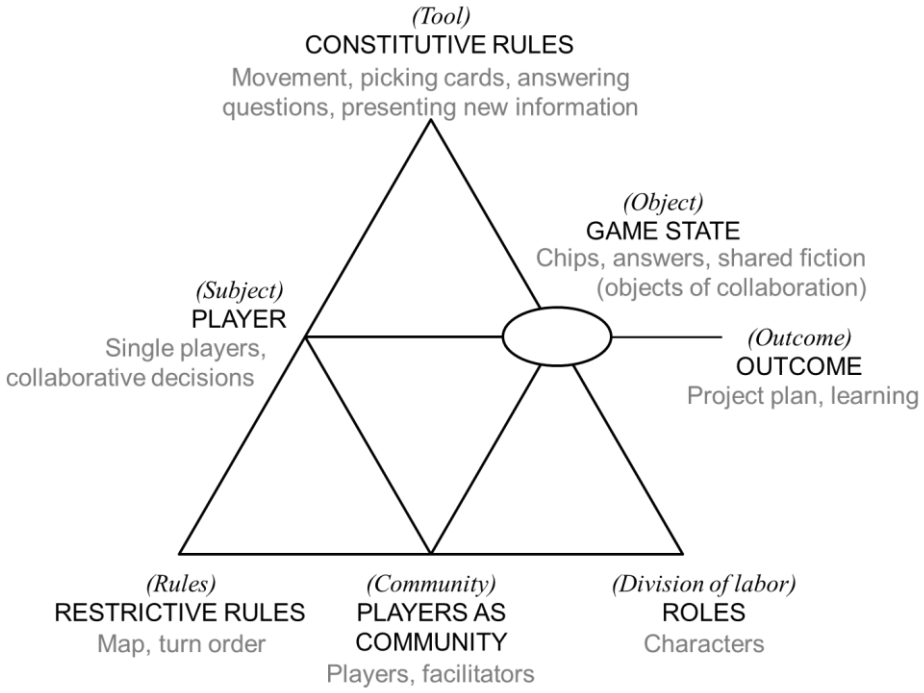

Figure 15 – The ATLAS game structure as an activity system

The person whose activity is modeled in Figure 15, i.e. the subject in the ATLAS game, is one player. However, because the ATLAS game is a collaborative game, the player's actions sometimes have to conform to the consensus of all players, expanding the subject of the activity to cover all players in situations requiring collaborative decision making. The player uses rules for affecting the tangible or intangible game states, the objects of activity. These rules include affecting the tangible objects of collaboration, such as moving figures, revealing tokens and drawing cards. The players also uses actions that affect the intangible states of the game, like proposing and developing answers to Question cards or bringing in knowledge from outside the game. The outcome in the ATLAS game is not a victory or a defeat for any of the players, but instead the outcome is the completion of the game and the "serious" outcomes of the game such as the project plan for service co-development and the learning the players have achieved with the help of the game.

The ATLAS game has many restrictive rules in addition to the constitutive ones regarding when and how to move, turn order, etc. However, the game does not have many rules regarding the manipulation of intangible objects beyond enforcing some

sort of consensus to encourage co-development, implying that the players are entrusted to enforce implicit rules on taking turns with the help of the facilitators.

The players of the ATLAS game form a community of knowledge (Lave and Wenger, 1991). While playing the game, the community is limited by the available knowledge they and the facilitators have, but the players also act as a collaborative unit that develops ideas and makes decisions. The roles in the ATLAS game community are first divided into player and facilitator, but the players also take on secondary roles based on their previous experience regarding service co-development, their personality and the roles they create for the characters.

In summary, different levels of objects (primary, secondary and tertiary) (Nicolini et al., 2012) are formed either by the game designers as predesigned objects or formed during gameplay based on personal experiences triggered by game material. The objects of collaboration form the game states that the players manipulate using the constitutive rules to reach the goal of the game, constituting the core activities of playing the game.

ERQ2: How does game structure facilitate knowledge co-creation as a process?

The second research question for the empirical study concerns the ability of game structure to support knowledge co-creation as a process. In theoretical framework, a model for three level of knowledge co-creation was presented for comparing different models of knowledge co-creation, and for analyzing which objects of collaboration could support each level.

The three levels of knowledge co-creation described in Chapter 5 (Table 5, page 38) are 1) monological transfer of knowledge form a sender to receivers, 2) dialogical translation of knowledge between multiple senders and receivers with the assistance of boundary objects and 3) trialogical knowledge transformation of existing knowledge into new knowledge by developing shared trialogical objects. Likewise, the observed process of game turns as a knowledge co-creation process in Chapter 8 (Table 13, page 70) can be divided into the three levels of knowledge co-creation detailed in the theoretical framework: monological, dialogical and trialogical.

The knowledge co-creation process begins with the monological level when the players roll a die, move a figure, draw a card and read the card aloud. As the game

turn progresses and the players start to present initial ideas and discuss them, the players move on to the dialogical level. However, the players move quickly to the trialogical level when ideas are not only agreed or disagreed with, but actively developed. Finally, once the ideas are no longer developed further, the players move on to developing their ideas into explicit statements with external artefacts. The knowledge co-creation returns to the monological level as the players begin the next turn and roll the die again. This progress is summarized in Table 16.

Table 16 – Game turn phases as theoretical knowledge co-creation levels

Knowledge co-creation phase	Level	Carlile (2002, 2004)	Paavola et al. (2004)
Proposing	1	Transferring	Monological learning
Negotiating	2	Translating	Dialogical learning
Co-developing	3	Transforming	Trialogical learning
Explicitation	3	Transforming	Trialogical learning

The game structure is used by the players to keep moving from one question to another and to reach level 3 with the assistance of the predesigned objects, supplemented by the emergent objects the players form during the game as both par and result of the knowledge co-creation process. Discussion is kept on the subject since the development of ideas is focused on the Question card being answered at that turn. Knowledge is being built on top of previous propositions rapidly, and established propositions are taken as fact instead of deliberately criticizing them, similar to swift trust at the beginning of collaborative relationship outside game structure (Jones and George, 1998).

9.2. ANSWER TO THE RESEARCH PROBLEM

As addressed in Chapter 1, the research problem of this thesis is:

How does game structure support knowledge co-creation?

Game structure supports knowledge co-creation by first providing a shared structure that supports knowledge co-creation as a process, and second by enabling players to form and use objects of collaboration that mediate knowledge co-creation within the game structure.

As presented in the theoretical framework, knowledge co-creation is a social process of collaboratively transmitting, translating and transforming knowledge across individuals and groups. Collaboration in knowledge co-creation is mediated by the objects of collaboration which enable, support and motivate collaboration, and are developed as a part of the knowledge co-creation process. In the empirical study, game structure was observed to provide multiple objects of collaboration and a temporal structure that enabled the game to progress with minimal interruptions.

The game structure, illustrated in Figure 15, provided the players with a common objective, shared objects of collaboration and tool with which to reach the desired outcome of creating a project plan for a service co-development project. The use of the tools provided to the players to manipulate both the tangible game material (cards, figures, notes) and the intangible objects (case context, services) enabled the players to form an innovative knowledge community that actively developed their own practices by developing the shared objects, and ultimately form the finished project plan. As the players developed their practices to reach the goal of the game, the developed practices resulted in new ideas and improved understanding of service co-development and co-development methods. The use of case context description and Question cards created an open problem for the players to collaboratively explore.

9.3. CONCLUSIONS

The objective of this thesis was to increase knowledge about the use of game structures in knowledge co-creation. The theoretical objective of the study was to provide understanding about how game structures could support knowledge co-creation as a tool and how objects of collaboration are used in game structure. The empirical study was carried out to reach these goals.

The temporal game structure followed a model describing three consequent levels of knowledge co-creation, established the theoretical framework: monological, dialogical and trialogical. Each game turn allowed the players to choose a topic for development, and during the turn, advance from monological to dialogical and trialogical knowledge co-creation, and build on top of the knowledge co-created on previous game turns. By following the game rules, the players were supported by the game structure in their knowledge co-creation process.

IV CONCLUSIONS

Objects of collaboration have a crucial role both as a part of the game structure itself and in supporting knowledge co-creation. The objects of collaboration used in supporting knowledge co-creation were not only readily available as game material, but the explicitly stated game outcomes of the game structure directed the players to use the predesigned objects of collaboration and form new objects as a part of the knowledge co-creation. This thesis presents a model for the game structure in the ALTAS game as an activity system, in which the objects of collaboration form the object of the game as an activity system, and suggests that the game states in all games could benefit from analysis based on the theoretical framework of objects of collaboration.

After contrasting the empirical results of the study with the descriptions of learning games (Squire et al., 2005) and planning games (Abt, 1987), both of which describe some elements of the ATLAS game, the results of this study suggest that the ATLAS game does not fit into either of these existing game categories. Because the intended outcome of the ATLAS game is not limited to the increase of individual players' knowledge as in the case of learning games, nor to providing effective and efficient methods for planning a project, the results suggests that knowledge co-creation games are a new game category. The analysis of the ATLAS game in this thesis contributes to analyzing, designing and developing other knowledge co-creation games.

10. IMPLICATIONS OF THE STUDY

This chapter describes the central implications of the results of this study. The findings are divided into practical implications which detailed recommendations for practitioners on the design and use of knowledge co-creation games, and theoretical implications which interpret the significance of the results for future research.

10.1. PRACTICAL IMPLICATIONS

The practical aim of this thesis was to provide understanding for how knowledge co-creation games can be designed and used to support knowledge co-creation. The practical implications described in this subchapter are intended for managers and professionals in service design, product development and other functions where a high degree of separation exists between areas specialization.

The results of this study suggest that knowledge co-creation games are an effective tool for supporting planning and forming a shared understanding in multidisciplinary groups that have limited existing shared practices. The shared objective and clear progression within the game structure provide opportunities for the players to form a shared understanding about the goals and methods of a project, but also to identify disparities between existing practices within the group.

The results of this study suggest the following guidelines for designing a knowledge co-creation game:

1. **Make it collaborative** or with very limited competition elements to incentivize the players to contribute towards the common goal of knowledge co-creation.
2. **Have well established but "fuzzy" question** or some other open-ended problem to for the players to pursue, and have game mechanics in place to keep the problem evolving. A static question is readily answered, but a problem that eludes the players even as they get closer to it constitutes an epistemic object that unites and motivates the players behind a single objective.
3. **Allow the players to establish new information** as they will be more than happy to decline the ideas of other players as unrealistic or poorly justified. This guideline may not work as well in the presence of established social ties

or power structures, so make sure that the players know they can disagree with other players, and develop the ideas into different directions than the player originally intended.

4. **Rules and artefacts should not hinder the progress of the game**, but instead provide "rails" that the players can progress on. Poorly timed questions or arbitrary die roll requirements add nothing to the knowledge co-creation aspects of the game, and can even decrease the engagement of the players. However, this guideline should not be taken as an encouragement to build a linear track of progression, as it deflates the tension of reaching the goal of the game.

The ATLAS game has been developed further using the analysis presented in this study. Multiple developed concepts have been made and one of them has been made into a prototype and assimilated into a new version of the ATLAS game.

The developed version built on top of the notion that the focus of the game should be on a trialogical object that would enable a higher level interpersonal co-development of ideas through collaboratively manipulating the shared object. Figure 16 presents a concept visualization, produced for developing the new version of the game. In contrast to the game used in the empirical analysis of this thesis, the developed game does not have a static game board, but instead the board is assembled during the game by the players from game pieces containing the questions from the three Island decks.

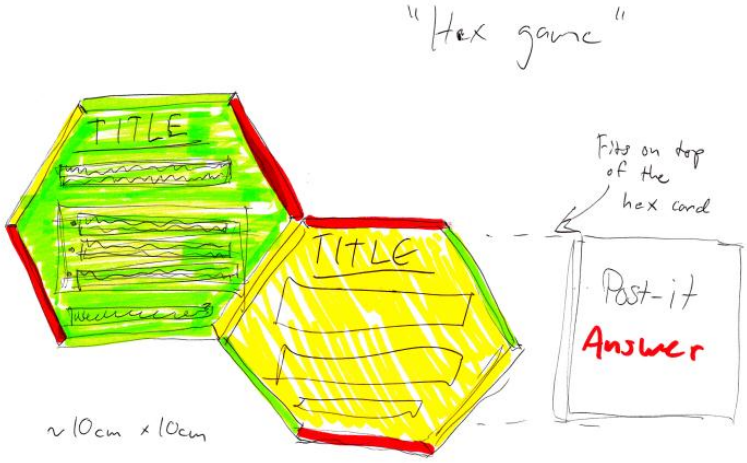

Figure 16 – A concept drawing of the "Hex game" with an example of placement

In the developed game, the gameplay revolves around creating a “map” by revealing and placing new tiles onto the game board around a starting tile. At the beginning of the game, the players set objectives for the co-development project they will plan during the game. Each revealed tile acts as a card for the purposes of posing questions and is placed on the board in relation to earlier tiles.

Figure 17 – Example of play of the developed version of the ATLAS game

The player in turn selects a stack of tiles sorted by type (e.g., Project Definition, Methods and Tools, Participants) and turns over the top tile. The player reads aloud the question in the tile and the players discuss what the question means for their project. The player in turn then selects an available edge of the “map” on the game board and places the tile there. Originally each tile would have colored sides that would have to be matched with previously placed tiles. However, preliminary testing proved that the knowledge co-creating aspects of the game are already so mentally challenging that a game-like color-matching element does not contribute to the game.

The player who places the tile must describe how the answers written on the connecting tiles affect the question on the new tile. This brings previously made decisions periodically up for new discussion, and helps the players find connections they might have passed by. Once the tile is placed, the players collaboratively answer the question on the new tile, and the player who placed the tile is responsible for writing the answer down on a sticky note or a similar surface that can be attached to the tile. Writing the answers down forces the players to reach some sense of

consensus on the answer, and placing all answers to the center of game area keeps them available for referencing and forming new connections.

The game is played by drawing, placing, addressing and answering the hex tiles until time runs out, all game tiles are placed or no more tiles can be placed. In the end, players have formed a map of answers that outlines the key elements of the project they have co-developed.

10.2. THEORETICAL IMPLICATIONS AND FUTURE RESEARCH

The theoretical objective of this thesis was to provide understanding into how game structure supports knowledge co-creation. Additionally, the objective of this thesis was to study the role of object of collaboration in supporting knowledge co-creation.

The use of objects in collaboration in the empirical analysis supports the claim by Nicolini et al. (2012) that the role of objects in collaboration cannot be explained using only a single theory for the function of objects, such as the theory of boundary objects in knowledge transformation (Carlile, 2004), and instead a plural view must be embraced. However, while new objects of collaboration were created during the game, no cases of objects changing from one role to another were observed as evidence for the temporal affordances of objects of collaboration suggested by Nicolini et al. (2012). This could be explained by the number of available objects which may have encouraged the players to merely adopt a new object of collaboration, as needs changed, instead of using a limited number of shared objects for multiple purposes. The objects of collaboration were also tied directly to the game structure, and the players were often given objects of collaboration specifically designed for that interaction, e.g. handing out Participant cards to the players when the players were asked to choose participants.

The results of this study suggest that the tangible and intangible materiality of shared objects needs a critical assessment. Previous research has implied that the materiality of practices is principally physical, as in the case of information infrastructure such as computers, software and the Internet (Orlikowski, 2007; Star and Ruhleder, 1996), or in the case of learning technologies (Hakkarainen and Paavola, 2009). Because the forming and use of intangible objects in a significant role in describing objects of collaboration in this study, the results of this study imply that further research into

the material aspects of practices needs to be expanded to address the forming and use of intangible objects, or even the role of ontologically fictional epistemic systems (Dolezel, 1998).

Based on the theoretical framework and the empirical analysis, the use of knowledge co-creation theory in game structure falls in between learning games, in which the outcome is individual learning, and planning games, in which the outcome is knowledge of external value, e.g. a project roadmap and timetable. The ATLAS game has two goals: the goal of creating the project plan, and the stated but not explicitly pursued goal of learning about service co-development methods. The parallel and complementary goals separate the ATLAS game from previous game categories, creating a new game category: knowledge co-creation games.

The development and analysis of the ATLAS game utilized theoretical concepts of knowledge co-creation, such as trialogical learning through developing shared predesigned objects to provide opportunities for knowledge co-creation. As such, the results of this study imply that further research into the use of games to support learning and knowledge co-creation should build on top the theoretical framework of knowledge co-creation.

The objective of this study was to understand how game structure supports knowledge co-creation. The findings of the empirical study are limited by the sample size of just one knowledge creation game, the format of the game being limited to a board game format in a face-to-face setting and the service co-development context the game was studied in. Future research regarding the use of knowledge creation games as a branch of serious games should explore the use of knowledge co-creation games across time, subject matter and media.

As multiple theories of knowledge co-creation (Bereiter and Scardamalia, 2003; Hakkarainen and Paavola, 2009; Nonaka et al., 2000) suggest that knowledge co-creation processes are temporally distributed over the course of an extended enquiry, the repeated use of knowledge co-creation games could be studied in the future. A longitudal study of knowledge co-creation games could explore whether using the games as a part of an organizational process or over the course of a project's lifetime would yield increasing, steady or diminishing returns and whether co-created knowledge could be retained from one game to another. A longitudal study could also provide insight whether a knowledge co-creation game could function as a tool

for expansive learning (Engeström et al., 1999) by allowing an organization to develop their practices over time using the game.

Future research regarding extending the use of knowledge co-creation games would introduce either the ATLAS game or an another knowledge co-creation game to a knowledge-intensive planning context either as an event, as in this study, or an organizational practice, as described above. Multiple-case study methodology could provide opportunities for comparing the ability of generic i.e. context-free, knowledge co-creation games compared to games customized to that particular industry or case. Such study could also present suggestions on how such contextualization could be done in collaboration with existing people working in the context with suggestions on how the ATLAS game could be improved to better fit service co-development context.

Since the ATLAS game was designed and tested as a board game used in face-to-face collaborative situations, future research should consider translating the mechanics of the ATLAS game into digital context or design a completely digitally native knowledge co-creation game leveraging the conclusions of this study. Research into cross-media use of knowledge co-creation games would enable the use of knowledge co-creation games as computer-supported collaborative learning (CSCL) (Gifford and Enyedy, 1999; Paavola et al., 2002).

11. EVALUATION

This study has been conducted using a literature review and an empirical case study. This chapter discusses the credibility, transferability, dependability and confirmability of the study (12.1) as well as its limitations (12.2).

11.1. CREDIBILITY, TRANSFERABILITY, DEPENDABILITY AND CONFIRMABILITY

The data collection and analysis of the single-case study with a nested multiple-case study (Yin, 2009) in this thesis follow a qualitative approach (Creswell, 2009). The study is therefore evaluated using four criteria proposed by Lincoln and Guba (1985) for evaluating qualitative study: credibility, transferability, dependability and confirmability.

Credibility refers to the truthfulness and persuasiveness of the causalities and relationships inferred (Guba and Lincoln, 1989). Credibility of the study is justified by the credibility of interpretations, external validation of the inquiry, continuous revision of hypotheses, and referential adequacy (Lincoln and Guba, 1985). The inference made in this study was made according to abductive reasoning, in which theoretical framework and empirical analysis inform one another over the course of the research, and the theoretical framework is chosen based on its ability to explain the empirical data (Dubois and Gadde, 2002).

As suggested by Heath et al. (2010), the video data was analyzed iteratively with peer debriefing over the course of the analysis to identify potential bias and clarify interpretations (Lincoln and Guba, 1985). As the video data of the cases was analyzed in multiple iterations (Heath et al., 2010), the analysis of each phase was documented as described in Chapter 7 and Appendix I. All video recording data used in the research has been archived in its “raw” form in order to provide referential adequacy for verifying the inference made in the study both later in the study and for external parties that may want to test the interpretations against the data (Lincoln and Guba, 1985). Links between the observations and the data have also been recorded in the analysis software Atlas.ti, described in the empirical analysis of this thesis, for reviewing the credibility of observations.

Transferability describes the generalizability of the findings, i.e. whether the findings can be applied in other contexts and to other research subjects (Lincoln and Guba, 1985). In this thesis, and in qualitative research in general, the transferability of findings cannot be determined by the evaluator of the study that is transferred, but instead by the receiver of the evaluation (Eisenhardt, 1989; Guba and Lincoln, 1989). In order to enable the receiver of the evaluation to assess whether the findings can be applied to some other context, this study provides thick description of the research context, theory, methods and findings of the study (Lincoln and Guba, 1985). In order to retain repeatability and transparency through the empirical analysis process, the decisions and changes were documented during the research as suggested by Jordan and Henderson (1995).

Dependability describes the consistency of the study with the aim of providing results independent from the researcher's identity (Guba and Lincoln, 1989). The causal relationships between observations and results was established over multiple watching rounds of the video data and progressively selecting more focused parts of the data for analysis, as suggested by Heath et al. (2010). Because the process of interpreting observations made from the data is fundamentally personal, transparency and reflexivity were pursued by writing down working theories and validating observations in collaboration with other researchers as suggested by the interaction research methodology (Jordan and Henderson, 1995). The individual observations made from the data were recorded using Atlas.ti software, where the operationalized concepts were connected to data to allow for reflection and discussion regarding the observations with other researchers.

The final criterion, confirmability, refers to the neutrality of the study i.e. that it is free of bias, values and prejudice (Guba and Lincoln, 1989). Confirmability is justified by ensuring that the findings can be traced to the data as an "audit trail" of inference (Lincoln and Guba, 1985). As established in the previous criteria, the empirical analysis of this study is based on video recordings that can be accessed along with the observations marked into the data using the video analysis software in order to allow inspection and confirmation of the findings (Guba and Lincoln, 1989). In addition, quotes and frames from the data are presented in Chapter 8 to support the empirical findings of this study.

11.2. LIMITATIONS OF THE STUDY

As a qualitative study, this study does not suggest that the results could be generalized across samples but instead used to develop the theoretical understanding of the phenomena researched in the study (Yin, 2009).

This study aims to provide understanding for the use of game structure to support knowledge co-creation based on two cases that follow replication logic (Yin, 2009). The two cases studied are similar enough in terms of setting, methods and participants to allow for replication, but the study does not offer findings that can be directly generalized to other cases (Yin, 2009). Instead, the documentation in this thesis allows transferability of judgments to anyone applying the study (Guba and Lincoln, 1989).

The game version used in this study was an initial prototype and the primary motivation for organizing the game sessions was to develop an improved version of the game. This raises the question whether the level of development limits the usefulness of the study, as an improved version of the ATLAS game has later been developed.

When analyzing game prototypes, or existing games on the market, to assess the effectiveness of using games in non-entertainment contexts, the study has to take into account that the particular game used may not represent the full potential of serious gaming, much like the use of any media should not be assessed using a single piece of work.

The data for the empirical study was based primarily on the game material and the video from a single fixed point video camera, with no supporting data to help understand the internal processes of players beside observations that can be made from the videotape and audiotape. This limits the analysis regarding the motivation and reasoning processes of the players and assessing the impact playing the game had for the players (Mayer et al., 2014). Additionally, the analysis of the video data focused on the speech acts and manipulation of game material, with a limited emphasis on nonverbal communication. This may limit the understanding of player motivation.

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APPENDICES

APPENDIX I – CASE 1 TURN LOG

Time	Duration	Section	Card drawn/ Question	Description
0:04:30	03:00	Explaining the rules	-	Basic game rules are explained
0:07:30	05:34	Selecting characters	-	Players collaboratively select five characters to represent different key developer types: “Möyhentäjä” (Stirrer) the private sector innovator network, “Puskija” (Pusher) the official who promotes the project, and “Aktiivi” (Activist) the regular citizen.
0:13:04	06:27	Selecting objectives	-	Players choose to take two objectives: “Bringing different parties together” and “Making an experiment”. A third objective is left as an unofficial objective: “Other unplanned or tacit goals.”
0:19:31	00:07	Turn 1	-	No movement
0:19:38	00:22	Turn 2	-	No movement
0:20:00	01:30	Turn 3	Mystery card: *"Prepare for workshops in advance"*	
0:21:30	01:10	Turn 4	Mystery card: *"Go back to Harbor of Change"*	The players decide not to reassign their objectives.
0:22:40	05:47	Turn 5	Project definition card: *"What is the reason for change?"*	The city is reacting to conditions that have already changed, but the project aims to proactively change the municipality to a more citizen-oriented way of working.
0:28:27	05:05	Turn 6	Project definition card: *"Are you developing a new service?"*	The project aims to create a new service in the sense that the municipality has not had a similar service.
0:33:32	01:43	Turn 7	Project definition card: *"At what point in service development are you?"*	The project is currently gathering new ideas.
0:35:15	01:40	Turn 8	Project definition card: *"Why do*	The participants are co-developers. Even the funders

			you want to involve the participants?"	are invited as co-developers in order to identify revenue sources for the municipality.
0:36:55	00:02	Turn 9	Participants card: *"Which participant group is the most challenging one to involve and how do you turn it into an advantage?"*	Old, stubborn citizen are invited to the project and used to market a traditional-oriented atmosphere. The decision makers are forced to make commitments and hard decisions.
0:36:57	01:59	Rules exception	-	Observing super game master instructs to move the "Möyhentäjä" character to the Island of Participants to speed up the game.
0:38:56	04:04	Turn 10	Participants card: *"Which participant group is the most challenging one to involve?"*	The most difficult groups are the senior citizen and the municipality decision makers. The senior citizen will be used to convey a positive, traditional atmosphere in marketing and the decision makers will be made to invest in the changes and make hard decisions to commit them.
0:43:00	03:21	Turn 11	Methods and Tools card: *"In what forms will you gather participant information?"*	Video clips from the municipality filmed by potential citizen, and video data from group interview workshops that use the clips as material for discussion.
0:46:21	02:34	Turn 12	Participants card: *"Select 2 most important participant groups."*	An artist, a factory owner, a soldier, a teacher and a soldier's wife participant is drawn. The players choose to include a financer and an artistic community in the project participants.
0:48:55	02:10	Turn 13	Methods and Tools card: *"What do you plan to organize?"*	The players decide not to have individual interviews but instead hold workshops and collaborative sessions. Exit polls for citizen leaving the municipality.
0:51:05	01:59	Turn 14	Participants card: *"How would you like the participants to participate?"*	The players decide to have financers and people moving into the municipality as co-developers.
0:53:04	01:31	Turn 15	Hint: *"When you organize collaborative*	Facilitator turns into a question: "Do you think how you use data gathered in your

			workshops be aware that they produce a lot of data."	work?" The players decide to use a predefined brief in the workshops that can be extended during the session.
0:54:35	05:24	Facilitator's question	Facilitator asks an additional question: *"Will you analyze video recordings or gather written feedback from the sessions?"*	The players decide that a moderator will help summarize a common understanding at the end of the session. In addition, a feedback form will be sent to the participants. You also have to communicate to the participants that something has been done based on their contribution.
0:59:59	00:30	Turn 16	Hint: *"Take breaks"*	-
1:00:29	01:29	Turn 17	Participants card: *"What kinds of skills of co-development are needed?"*	The players though all of the examples were relevant, especially being visionary.
1:01:58	00:53	Turn 18	Participants card: *" Select 2 most important participant groups."*	Fisherman, police, farmer and his wife and son are drawn. The farmer's son is chosen as a representative of the next generation to produce ecological food and a fisherman to energize the industry.
1:02:51	01:40	Facilitator's question	Facilitator asks an additional question: *"How do you reward these new participants?"*	The players decide to establish an innovator award. The participants have to be motivated to develop their own community, which is its own reward.
1:04:31	00:00	Game end	-	The game ends and the players are briefed to tell to the other groups how their game went after the break.

APPENDIX II – CASE 2 TURN LOG

Time	Duration	Event	Card drawn/ Question	Description
0:00:00	02:11	Explaining the rules	-	Explaining the rules
0:02:11	03:14	Selecting characters	-	The players choose roles that reflect their personal roles: a steadfast speaker for the common man, the junior developer and the ideator who skates from one project to another.
0:05:25	02:11	Selecting objectives	-	The players choose to select three objectives that they think best reflect the task of empowering citizen of the city given to them in the case: **Bringing together**, **Making an experiment**, and **Changing organization culture**.
0:07:36	00:32	Starting the game	-	Movement rules are explained and the player to take the first turn is determined.
0:08:08	00:58	Turn 1	Mystery card: "*Give one Method card to the game master"*	The players do not have Method cards to lose so the card is ignored.
0:09:06	00:29	Turn 2	Mystery card: "*Remember to gather data from collaborative feedback sessions"*	The players make note of the hint and move on.
0:09:35	01:57	Turn 3	Project Definition card: "*Are you creating a new service, developing an existing one or something in between?*"	The project aims to create a new service. The players agree to enable better life through a service that increases the sense of community across boundaries.
0:11:32	02:15	Turn 4	Project Definition card: "*What are you trying to create? A shared understanding of the service concept? New ideas for developing a service? Something else?*"	The players decide to focus on the relationship of the two cities. Creating a shared understanding of a service.
0:13:47	00:54	Turn 5	Mystery card: "*Lose one of your*	The players do not have Participant cards to lose so the

			participant cards"	card is ignored.
0:14:41	01:16	Turn 6	Mystery card: "*Be conscious of the language you use in workshops."*	The players make note of the hint, and decide that they too should be conscious about how they as players of the game may understand terms differently from each other.
0:15:57	03:58	Turn 7	Participants card: "*Take 5 participants cards, choose 1- 2 most important to involve."*	The players choose to involve a **factory owner** for commercial a viewpoint and financing and a **farmer** for communal, ecological and earthly viewpoints. The two are seen as polar opposites balancing each other. The concept of better life is developed by connecting it to earthiness.
0:19:55	07:01	Turn 8	Methods and Tools card: "*Take 5 Methods and Tools cards and choose 1-2. How could they be used?"*	The players choose **crafting** and **scenarios** and left out comics, prototypes and observing. Crafting would be used for participating across language boundaries and scenarios are made by the citizen to communicate their needs. Participants could choose either one of the methods as they felt fitting. As a projected result the citizen would be empowered to create pop-up events around the theme of spring sow.
0:26:56	01:51	Turn 9	Methods and Tools card: "*Is the main focus on gathering knowledge or generating ideas?"*	The focus is on generating ideas and future visions instead of gathering information about the current situation.
0:28:47	04:32	Turn 10	Participants card: "*Which participant group is the hardest to involve."*	The players decided to focus on working aged citizen since they are hard to get to participate. Bilingual citizen can also be challenging because of language barriers.
0:33:19	02:33	Turn 11	Participants card: "*How do you want the participants to participate? Source of information, co-developers or both?"*	The players identify that having the participants as co-developers would be ideal and connects with the case aim. The players note that groups and associations are easier to involve than individual middle-aged citizen.
0:35:52	02:32	Turn 12	Methods and Tools card: "*What*	The players agree that the selected methods are used to

			are you trying to learn?"	find out the behavior and values of the participating groups in order to find common ground. This knowledge is used to develop services that enable the better everyday life.
0:38:24	03:50	Turn 13	Methods and Tools card: *Whose perspective, knowledge and skills are the most important?*	A facilitator points out that the players can think whether they are lacking some participant groups form the two they have selected. The players feel that while retirees are absent they already have a lot of time and opportunities to participate in developing public services. The youth are also absent and youth unemployment is a current subject. At a facilitator's initiative, the players leave the question unanswered at this time as a "representation question".
0:42:14	02:54	Turn 14	Participants card: "*What kinds of skills of co-development are needed?*"	Based on the methods they have chosen the players feel that imagination and context information are the most important skills of the participants since the project aims to generate ideas.
0:45:08	01:12	Super game master's question	The super game master pauses the game: *"Go through the material you have and determine whether you are missing some information or questions from some category."*	The players feel that they have quite a lot of information who to participate and how, but not enough substance on which sector the service will operate in. The players decide to further explore the Island of Project Definition to determine the substance information.
0:46:20	02:06	Turn 15	Project Definition card: "*What is the reason for change?"*	The players recall that the case mentioned many undergoing initiatives in the city but they had not had any real effects yet. The players decide that the project they are developing aims to make a concrete change where the other initiatives have not.
0:48:26	02:56	Turn 16	Methods and Tools card: "*Take 5 cards, how can they be implemented? Consider whether to emphasize*	The players feel that the methods they already have are oriented towards participation and they would now want more structured and concrete methods. The players choose **process models** and **focus**

			rationality or empathy and choose 1-2 cards."	**groups**.
0:51:22	01:22	Turn 17	Project Definition card: "*What point in development are you?*"	The players decide that the project is situated at the very beginning of creating a service, gathering ideas and identifying demand.
0:52:44	04:39	Turn 18	Mystery card: "*Help participants articulate their expectations and take them into account.*"	The players emphasize communication and expectation management towards session participants and stakeholders so that the expectations do not become too high but the participants still get a feeling that their contribution has been worthwhile. A virtual tool could be used to communicate to the public in which phase the project is in.
0:57:23	00:51	Turn 19	Project Definition card: "*Why do you want to involve participants?*"	The players want to involve the participants to create the content of the new service or services.
0:58:14	03:16	Facilitator's question	A facilitator initiates returning to the representation themes of turn 13: *"Who else will you need to involve in developing the service?"*	The players ponder what kind of service are they planning in the project since choosing the participant groups depends on subject matter? The players come up with a concrete service platform concept, the community square, to promote local food and earthliness. Culture services can also be developed in the vicinity of the square.
1:01:30	13:10	Moving to Implementation phase	-	A facilitator instructs the players to head back to the Harbor of Change once they feel they have enough material for drafting a project plan. The players feel they are ready for drafting the project plan and decide with the facilitators that a player will take a special "flight ticket" to the Harbor as an improvised rule to quicken the game.
1:14:40	07:39	Preparing the project plan	-	The objectives chosen by the players at the beginning of the game emphasized experimentation and new ideas. The service will be a platform for the citizen' own project ideas that are put into a

				web service where all citizen can vote on which should be implemented. Resources for good projects come from the city and corporate sponsors of the square who have visibility on the square. Funding is prioritized to projects that have citizen interest and attract sponsors. Project is named POPulate.
1:22:19	00:00	Game ends	-	The game ends and the players move to a break before presenting their project plan to the other table.