Degree project

Technology Enhanced Learning (TEL)
Development and Research:
An infrastructural study

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Abstract

Despite the availability of the advanced technologies and presence of Information and Communication Technology (ICT), the ICT applications and systems are under-exploited, i.e. underused, in learning environments. While the ubiquitous ICT in learning environments are surrounding us like other infrastructures in the modern time; we may consider them as an *infrastructure* and their development as an *infrastructure* development rather than isolated application and system development. This thesis is investigating the current practices of R&D in Technology Enhanced Learning (TEL), in order to illustrate their likeliness to an infrastructure. Accordingly this investigation will picture the socio-technical elements and the possible issues arising from the current practices. It also discusses a primary framework for TEL research and development as an infrastructure. Social construction of technology (SCOT) insight helps to realize the societal circumstances and socio-technical dimensions. In addition current experience in Cyberinfrastructure studies is used to guide the thesis to analyze the issues and the primary framework. This qualitative study is an attempt to highlight the challenges and to extend new approaches to the way TEL research and development is perceived.

**Keywords:** Infrastructure, Technology Enhanced Learning, Infrastructural Studies, Science and Technology Studies
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<tr>
<td>CI</td>
<td>Cyberinfrastructure</td>
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<td>CSCL</td>
<td>Computer Supported Collaborative Learning</td>
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<td>EPOR</td>
<td>Empirical Programme of Relativism</td>
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<td>ICT</td>
<td>Information and Communication Technology</td>
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<td>IT</td>
<td>Information Technology</td>
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<td>R&amp;D</td>
<td>Research and Development</td>
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<td>SCOT</td>
<td>Social Construction of Technology</td>
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<td>SST</td>
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1. Introduction

“The most salient characteristic of technology in the modern (industrial/post-industrial) world is the degree to which most technology is not salient for most people, most of the time.” (Edwards, 2003, p. 185).

We live in a world that Information and Communication Technology (ICT) is present in our life more than ever. Geoff Walsham (2012) points out the tremendous changes in ICT presence in our life since mid-1980s. ICT usage has grown and “technology is ubiquitous in many people’s personal, as well as their work lives through various social networking technologies” (Walsham, 2012, p. 88). ICT, like the other technologies, is an important part of our modern life (Misa, 2003) and it would be the right question to ask, how this technology is built? Is there any option other than what we have been given? And whether we are able to make decision and select among various options. Despite lack of classic literature with the focus on the technology, in the last two decades there have been valuable efforts to theorize the role of technology, particularly ICT, in the modern society (Hanseth, et al., 2012). There are many recent social theories which are concerned with the presence of technology in our life (Wajcman, 2002). In these theories “much emphasis is placed on major new clusters of scientific and technological innovations, particularly the widespread use of information and communication technologies, and the convergence of ways of life around the globe” (ibid, p.347).

Science and Technology Studies (STS) has been one of the leading theories which share the concern of presence of ICT in our life. The use and design of computing and information technology have become topic of STS in last two decades (Star & Bowker, 2006). STS have been studying construction of ICT artefacts, trying to open “black box” of the technology “to allow the socio-economic patterns embedded in both the content of technologies and the processes of innovation to be exposed and analysed” (Williams & Edge, 1996, p. 866). The STS social, economic, political and technological studies suggest and theorize various interests and concepts over last decades with sometimes contradictory results (Howcroft, et al., 2004). One of the key concepts of the social constructivist approach, under STS, is that:

There is a “choice” in “design of individual artefacts and systems” and “direction or trajectory of innovation programmes”, perhaps not always conscious (Williams & Edge, 1996, p. 866). This means: “Different routes are available, potentially leading to different technological outcomes.” (ibid, p.866)

As a social process, “relevant social groups” have their “interpretation” of certain artefact (Howcroft, et al., 2004, pp. 339-340) which results in “negotiability” of the “‘technological’ or ‘social’ outcome” (Williams & Edge, 1996, p. 867). So we know that we have or we did have a choice to make the technology as they are now or they will be in future.
1.1. Toward an Infrastructure

In twenty first century, ICT has joined other technologies that we are less aware of their presence (Misa, 2003). Our modern life means being among many of technological artefacts such as water supplies, telephones, railroads and so called “infrastructures” (Misa, 2003). Indeed, Information System (IS) researches could learn from those existing traditional infrastructures’ historical background, research and development.

Firstly, Infrastructures are crucial part of modern and post-modern time. We cannot imagine our life in twenty first century without those technological advances (Misa, 2003). Secondly, learning from these historical research and development, we might be able to plan for complex information systems of our time (Edwards, et al., 2007).

P.N. Edward argues that Infrastructures are “sociotechnical in nature” and are referred as infrastructure, not only for their hardware characteristics but also for “socially communicated background knowledge, general acceptance and reliance and near-ubiquitous accessibility” (Edwards, 2003, p. 188).

So by becoming an ordinary, available, accessible and transparent in our daily life, these technologies become an infrastructure. These characteristics of infrastructures are discussed by other researches in the STS literature such as (Star & Ruhleder, 1996) (Bowker & Star, 1999). They attempt to redefine the notion of infrastructure “in favor of a more flexible and complex notion better suited for analyzing the role of information technology in information society” (Dahlbom, 2000, p. 213).

One of the influential infrastructural studies is the analytics provided by Star and Ruhleder (1996) with a focus on the use issues of a large information system for collaborative scientific research, Worm Community System (WCS). Infrastructural approach to WCS “affords an understanding of the complexity of relations between technology and the way it is used.” (Bygholm & Nyvang, 2009, p. 33)

In their research, Star and Ruhleder (1996), focus on use issues of the developed system for WCS. From infrastructural perspective these issues are categorized in three groups. First group of issues are initial issues such as installation which user would figure out how to gather requirements of a new information system and install it. For example a simple task of purchase of parts and equipment is identified as first order issues. The second group issues are rather contextual and sometimes because of the several first order issues which are summed up. For instance, if the same purchase is limited because of rules and regulations within the organization or the equipment do not match the standards, then that is considered second order issue. The third group of issues are result of conflicts among different contexts and it occurs when decision are supposed to be made. I will come back to these theoretical discussions in detail later in this thesis.

These categories as I will explain shortly, provides the insight for ICT research and development teams in which to address the system usage in a more comprehensive manner.

1.2. Learning and ICT

The focus of this thesis is on learning, in both formal and informal form and the ICT systems and applications which are developed to help various learning methods. In particular, I investigate the research and development of ICT systems and applications for learning purposes.
Technology Enhanced Learning (TEL) as a technological intervention in learning environment grows rapidly in today's fast-paced technological inventions and innovations. TEL has become a "global phenomenal" (Gulati, 2008, p. 1). TEL is supposed to carry out an important role in reaching a wide range of children and adults across the globe to overcome socio-economic gaps, to promote democratic ideas and reduce social exclusions (Gulati, 2008).

Currently the “ubiquitous” learning ICT emerges in numerous forms in the learning environment (Huang, et al., 2009) (Dillenbourg, et al., 2009). Various entities, roles, relationships and viewpoints are engaged in the complex setup of teaching and learning landscape (Salavati, 2013, pp. 66-67). There is a massive investment in different levels of formal education including primary schools and universities (Ruth, 2010). However currently among TEL researchers the need for a comprehensive approach is emphasized (Dillenbourg, Järvelä and Fischer, 2009; Kukulśka-Hulme, et al., 2009).

Technology Enhanced Learning (TEL), despite its great achievements in the last three decades, is facing a number of challenges including underutilized systems and applications. For example teachers still remain reluctant to use IT tools in school (Huang, et al., 2009). This may happen for several reasons. Perhaps we could reconsider the technology itself which is developed for learning purposes (Dillenbourg, 2013). The question is that “is there something about the technology we develop that discourages its usage?” (Dillenbourg, 2013, p. 485).

Star and Ruhleder (1996) have classified the use issues in their infrastructural studies. Within TEL era, according to their categories, the first group of issues are about “installation and use of system” (ibid, p.118). This could be the capability of teachers and students to install and make the different applications work or difficulties upon purchase of a new system such making proper decision among the available options. The second group of issues is context related which have attracted many in TEL research era such as context aware systems and adaptive systems. Either system is used within school environment or outdoor setup, students and teacher would face different challenges and every student could feel different about the system depending on their skills or classroom cultures. Finally the third group of issues is about alternatives in use and the conflicts of meanings among various actors. In TEL literature concept of “Orchestration” addresses these multi-device and multi-layered contexts. Group of TEL researchers are suggesting the term of “orchestration” to represent the complexities of current ICT design and use in learning environments. “Orchestration” is developed by Dillenbourg (Dillenbourg, Järvelä and Fischer, 2009) and other colleagues around the classroom learning environment and it “refers to how a teacher manages, in real time, multi-layered activities in a multi-constraints context” (Dillenbourg, 2013, p. 485).

As mentioned above infrastructural studies and the related approach have a comprehensive approach pertaining development and use of ICT. In my thesis I will investigate the research and development of a TEL research center to explore what the practices are and how the research and development is performed. The related group of people, problems and their solution are analyzed while taking into account that what is supposed to be developed is an infrastructure, not an isolated application or system with its defined dimensions. The thesis attempts to analyze the options for TEL development and to look for answers on how these options are selected. I will ask about the efforts and challenges toward research and development of TEL artefacts which are perhaps the future infrastructural artefacts.
1.3. Problem Statement

The concern of this thesis is the ICT and its use issues for learning purposes. Why ICT is “under-exploited”, i.e. underused, in learning environments? In particular, the question is that “is there anything wrong with the technology?” (Dillenbourg, 2013, p. 485). Despite the massive investments on the e-learning and Technology Enhanced Learning (TEL) projects (Ruth, 2010), the challenge still remains to engage teachers and students to use technologies provided for learning purposes.

Being a student, I have witnessed the problematic situations which the lecturers have to deal and manage the classroom scenarios with ICT systems and applications. As the literature such as (Dillenbourg, 2013; Dillenbourg, Järvelä and Fischer, 2009) suggest, those issues are phenomenal.

Competitive marketing of new products and fast evolving of ICT hardware and applications (Andrews & Haythornthwaite, 2007) are listed as the reasons for forcing technologies into learning environments. This rapid involvement of information technology would cause the disengagement of the actual users—teachers and students—with ICT (Dillenbourg, 2013).

It is very important to acknowledge that the use of technology is not solely because of how good the technology would be but also it depends on the existing technologies surrounding that new technologies. The current trend as taking ICT development as isolated application development (Lee, Dourish and Mark, 2006) (Bietz, Baumer, and Lee, 2010) (Lee, et al., 2012) (Jirotka, Lee and Olson, 2013) has leaded to the use issues in major ICT developments.

Apparently the current use issue is not limited to Learning technologies and learning from other major ICT developments could help address use issues in learning and education ICT related projects.

1.4. Aim and Research Questions

This thesis aims to explore the Technology Enhanced Learning (TEL) research and development (R&D) through investigating the parties involved, the current challenges and the issues addressed by those R&D developments and finally the TEL R&D characteristics as an infrastructural development.

I ask questions about the stakeholders (i.e. who are they?), the research approaches and aims, the projects and the challenges in a TEL research group to find out what matters for researchers and how the R&D activities are done (i.e. What they do? And how they do it?) And what are the characteristics of those activities they are (i.e. Why they do?).

I will answer the following questions within this thesis, based on the literature and data gathering:

1. What could be the related groups, the activities and the perceptions in the TEL research and development?
2. Which issues are addressed by TEL R&D development?
3. What are the characteristics of TEL development as an infrastructural development?
1.5. Scope and Limitation of the Study

This thesis is limited to one group in Technology Enhanced Learning (TEL) research and development. It is bounded to the group’s activities which serve the TEL research and development. This includes their methods, materials (digital or physical) and policies which have been applied during last ten years. This may constrain the generalizability of the results.

However the center has enjoyed close cooperation with various European research center attempting cutting-edge research and development in TEL. Also the group’s papers have been published together with well-known research centers across the Europe. So I have found this group of researchers as one of the very good and leading example of TEL research and development groups in Europe.

From theoretical point of view, this study is limited to the notion of infrastructure and the way STS or SCOT sees the ICT systems, however there are other theories that are used to analyze the relationship of technology and practice (Bygholm & Nyvang, 2009). The shared strong point of SCOT and STS, in my opinion, is their focus on society as much as the technology which provides powerful tools for analyses of complex situations for IS.

Respondents to this thesis are some but not all of the researchers of the center. So they may cover certain activities of the group. This means the thesis is limited to the facts which are provided by those participants and their knowledge of the group. Also the interviewees are limited to R&D members. The users (e.g. teachers and students) and other stakeholders would be great resources of empirical data for future researches.

1.6. Contribution of the Study

From my own work experience, I always believe that ICT professionals are able and should do their best to provide better and more useful solutions for the society. I hope my thesis will encourage TEL research and development to broaden their activities and collaborate more vigorously in future.

I pursue a new insight, i.e. TEL as an infrastructure, into TEL and related research activities in order to achieve a comprehensive approach. In this approach the system development and/or application development is seen as Infrastructure development which has wide and ambitious target in long term. In one hand TEL is observed as socio-technical development. In another hand TEL system/application is seen within a broad landscape of education and not just an isolated system or application.

With help of Social Construction of Technology (SCOT), we may shed lights on social and cultural facts and their relationships to the modern technology. Learned from Cyberinfrastructure studies, Infrastructural studies move from standalone system/application development to consider broader interrelationship and interdependencies to the existing systems, applications, technologies, policies and etc. This is an attempt to build a “better world” (Walsham, 2012, p. 89) and may lead to better and more useful ICT presence in learning environments which could enhance our society as a whole.

According to Jacobson & Reimann (2010), when inventions in technologies are deployed and used in learning environments, inventions become innovations. Since this study is powered by STS studies which have design and use considerations (Star &
Bowker, 2006), this thesis will suggest some elements of an emerging research and development characteristics as a R&D framework in TEL R&D.

1.7. Structure of the Dissertation
Structure of thesis is essential in which “hold together” the research, “supports the purpose” and “enables to address” research questions “in ways that are appropriate, efficient and effective (reliable and valid)” (Hart, 2005, p. 313).

In the next chapters, firstly the theoretical bases of the thesis are presented. The theory section includes both the theories which is used to justify the method and also the theories that helps to analyze the finding and make meaningful conclusions.

In empirical finding section, I will detail the empirical and the facts from the interviews and continue by the analyses and discussion sections. Final sections is the conclusion section to summarize results describe my feedbacks.

The design of the thesis is guided by the way ICT systems is seen in Science and Technology Studies (STS) as “Infrastructure”, Infrastructure as an artefact which is built upon many other artefacts. Social Construction of Technology (SCOT) theories will guide the analysis of empirical results to answer the research questions for the related groups, problems and solutions.

Figure 1 illustrates the relationship among the author, the subject and its relationship with other elements. I do study a TEL R&D center that is engaged to multiple parties to carry out their research. The R&D center provides system/application for teachers/students and collaborates with many third parties in their researches.

![Figure 1 Research Design](image-url)
2. Theoretical Framework and Literature Review

In the coming sections I will present the related concepts from Social Construction of Technology (SCOT), infrastructural studies and Science and Technology Studies (STS). This may illustrate how technology is seen from theory’s perspective and also the relationship between various concepts which are presented. I will explain some of the major concepts that will prepare the stage for the methodology, data collection and analysis.

A research (Jacucci, Hanseth and Lyttinen, 2006) identifies three aspects of complexities in recent IS research as technical (e.g. increased computing power), organizational (e.g. dramatic structural and operational transformation) and societal aspects (e.g. interdependent organizational and social relationships across the globe). Then they advise:

“We need to change, adapt and deepen the range of theoretical frameworks that help conceptualize and understand complexity, and generate strategies to mitigate its effects during the design and use of information systems.” (Jacucci, Hanseth and Lyttinen, 2006, p. 6)

2.1. Social Construction of Technology (SCOT)

I briefly go through Social Construction of Technology (SCOT) theory and later few concepts from SCOT literature are presented to explain the way that ICT development process is understood.

2.1.1. The Social Constructional of Facts and Artefacts

Science and technology, facts and artefacts, have been studied by sociologists and sociological approaches in twentieth century. Social Construction of Technology (SCOT) has been one of the leading discourses. They have started using “interpretive sociological approaches” to make use of those sociological analyses of technology and science (Howcroft, Mitev and Wilson, 2004, p. 329). Such an approach “examines the content of technology and offers an exploration of the particular process and context that frame the technological innovation” (ibid, p.329).

Pinch and Bijker (1984) report on how “new knowledge” and “technological innovations” are sought to be emerged and how social constructivist ideas presume science and technology and their relationship.

They review the studies which are equally treating of the scientific truth and/or scientific falsehood. They believe that:

“All knowledge and all knowledge-claims are to be treated as being socially constructed: that is to say, explanations for the genesis, acceptance and rejection of knowledge-claims are sought in the domain of the Social World rather than in the Natural World.” (Pinch & Bijker, 1984, p. 401)

This social constructivist understanding of science helps to understand the process in which these scientific facts are generated (ibid, p.401).

The immediate consequence of this approach is that “there is nothing epistemologically special about the nature of scientific knowledge: it is merely one in a whole series of
knowledge cultures (including, for instance, the knowledge systems pertaining to 'primitive' tribes” (ibid, p.401).

In another hand, technology is also believed to be socially constructed. For this reason, there is no clear line between science and technology and both are socially constructed. Both scientists and technologists use the knowledge and techniques from cultural resources. “In other words, science and technology are both socially constructed cultures and bring to bear whatever cultural resources are appropriate for the purposes at hand” (ibid, p.404).

2.1.2. They might have been otherwise

If we believe in the constructivists understanding of the technology and science, the next question would be how it happens. Bijker & Law (1992) provide an example; the political decisions and lack of fund had determined construction of one bridge in US which had left the bridge in certain vulnerability. Those vulnerabilities were known for engineers and they were aware of them in case of earthquake. This means that the bridge would be built differently if it was a pure engineers’ choice to make the decision. However the bridge was built, neglecting the vulnerabilities, and the bridge collapsed in an earthquake incident. This reiterates the fact that technological developments are affected by society and its cultural resources as well as the actors.

Social Construction of Technology (SCOT) believes that “technologies do not, we suggest, evolve under the impetus of some necessary inner technological or scientific logic” (Bijker & Law, 1992, p. 3). But to answer how the technologies have become what they are, we may want to look into various facts including engineers’ initial thoughts and assumptions, the way technologies are used or misused, constrains of development and deployment and etc. (Bijker & Law, 1992)

Another example within the history of technology is the history of “Bakelite”, type of resins, early in twenties century (Pinch & Bijker, 1984). Bakelite was not popular in the market at the beginning. Later in 1918, after First World War and the dumping of the phenol which is used to make Bakelite, the Bakelite production spreads (ibid, p.406). This example is also a story of economic factors which determine technical advances.

2.1.3. Development Process

Social Constructivist of Technology (SCOT), as Pinch and Bijker (1984) describe, holds key concepts which will be explained in this section.

Basically SCOT’s approach to development process opposes linear understanding of innovation and production of their time, 1980’s, and it follows Empirical Programme of Relativism (EPOR) approach. This liner approach is shown in figure 2. This process flow presents the innovation process of single product with single input/output, starting from the research lab until the end user of the final industrial product. However it fails to engage the complexity and diversity of the factors and possible choices along the way which the end product is made.
In contrast, SCOT suggests that “the developmental process of a technological artefact is described as an alternation of variation and selection” (ibid, p.411). SCOT’s approach is a “multi-directional” model which “is essential to any social constructivist account of technology” (ibid, p.411). By such approach we would be able to describe successful and failed options and the “selection” in development process of technology. In the development process, Pinch and Bijker identify three key elements beside the artefact itself, relevant social group (section 2.1.3.1), and interpretive flexibility in the issues from relevant social groups’ perspective (section 2.1.3.2) and the stabilization and closure to the issues (section 2.1.3.3).

2.1.3.1. Relevant Social Groups

A social group, who gives meaning to the problem, decides which problem is relevant to the artefact (Pinch & Bijker, 1984). According to Pinch and Bijker (ibid) “Relevant Social Group”:

“is used to denote institutions and organizations (such as the military or some specific industrial company), as well as organized or unorganized groups of individuals. The key requirement is that all members of a certain social group share the same set of meanings, attached to a specific artefact.” (ibid, p.414)

A group of people, who share same meaning of an artefact, could be easy to recognize such as “users”. However it is not always the case and some, as Pinch and Bijker (1984) report in their case as “anti-cyclists”, are relevant social group same as the actual consumers of the bicycle.

To identify the relevant social group we should be looking for social groups which have a shared meaning toward the artefact. For example, in their report about bicycle development, women make their own social group because of specific meaning and use of bicycle. Bicycle for men was seen as a sport tool while it was used by ladies for shopping and it was part of their daily life.

2.1.3.2. Interpretive Flexibility

According to Pinch and Bijker (1984), in every technological development process, every relevant social group provides different meaning of an artefact and constitutes different problems, so there is no “just one possible way, or one best way” (ibid, p.421). As a result “there is flexibility in how artefacts are designed” (ibid, p.421).

They report an example of development of inflatable tires in late nineteenth century. Inflatable tires were new idea for cycle engineers and vibration issues in those years and many groups of consumers and engineers had different approach. For some it would reduce the vibration issues in the wheels. For others it was more of a good news about a higher speed. For number of engineers these innovations looked an ugly, insufficient
and troublesome solution and they believed it will be difficult to keep the pumped-air in the tires under the pressure. These engineers would suggest other solutions to the vibration issues instead.

Within Information System literature, “interpretive flexibility is a useful technique of deconstruction, since it shows that neither an artefact’s identity nor its technical “working” or “nonworking” is an intrinsic property of the artefact but is subject to social variables.” (Howcroft, Mitev and Wilson, 2004, p. 340)

2.1.3.3. Stabilization and Closure

“Closure” or the consensus upon a scientific fact is the latest, perhaps just partially, stage in Empirical Programme of Relativism (EPOR) and social construction of scientific facts in the innovation process. Similarly Pinch and Bijker define “stabilization” of an artefact as emergence of consensus in technological development. They discuss that within technological stabilization, it is possible to analyze the stabilization among more than one social group. Also in the analyses of the stabilization, one should agree of stabilization and the context. A simple example of stabilization of an artefact is to solve a problem and to provide solution which would invent an artefact. However this is not always the case.

One sort of stabilization in technology is “Rhetorical”. “Rhetorical” closure of an artefact means that the problems just disappear (Pinch & Bijker, 1984, p. 426). In this case, there will be no attempt to re-examine the claims or solve the problems. As they assert, even an advertisement can close the case of controversy by a simple claims. For example, a simple claim of the safety of the bicycles in their case has done the job and has closed the case.

Another way would be by redefining of the problem (ibid, p.428). Earlier I discussed the inflatable tires and their meaning for different social group. Pinch and Bijker report that the consensus was reached after the success of the tires in racing against the rivals in racing matches. So the problem was redefined from low vibration to higher speed for some social groups. Again in this type of stabilization the problem is not solved. Only the problem is not a problem anymore for the relevant social group.
2.1.3.4. SCOT Development Process

The relevant social groups bring various conflicts to the development process, such as conflicts in technical requirements, conflicts in solutions to same problems and moral conflicts. Every artefact has various meaning to different social groups and every social group constitutes different problems toward the artefact. Then every set of problems would result in different solutions which would end up in an artefact itself. This development process is illustrated in figure 3. So the development process of the artefact is result of the selection of choices, among the conflicts of social groups, and the stabilization in solutions and artefacts.

As Figure 3 shows, one artefact may relate to different social groups. Each social group may see different problems related to that artefact and different problems can result in a solution and/or stabilization.

Figure 3. Relevant Social Groups, Problems and Solutions in the Developmental Process of an Artefact (Pinch & Bijker, 1984, p. 418)
2.2. Critics on SCOT Approach

Like other theories, SCOT face critics of other scholars. Although these critics are beyond the scope of this thesis, I briefly mention few major concerns.

SCOT, as presented in 2.1, is analyzing the development process; however the consumption of the technology would result in reshaping the technology (Howcroft, Mitev and Wilson, 2004). For example, as it is discussed in 2.3.3, an artefact and its standards would expand of “positive feedback” and this “post development” process is not considered in social constructivist’ early discussions (ibid).

Further points are raised about the limit of the analysis and its focus to the micro levels. While we consider group of developer, for example, we may neglect the bigger picture which is affecting those development processes (ibid).

Political biases and moral issues seems are less discussed in SCOT studies (ibid). This is a matter of either narrowing the scope of analyzes and/or the lack of concern about moral and political issues.

In defend of recent related researches, as is followed in this thesis, I will discuss the notion of infrastructure which a) is deeply engaged with use and consumption of the technology, b) the artefact is seen in wider connected networks and not an isolated system and c) the relational dimension of artefact is discussed so contextual, moral and politics have more chance to be highlighted.

2.3. Infrastructural Studies

Our modern life means being among technological artefacts like water supplies, telephones, railroads, so called “infrastructures” (Misa, 2003). Learning from their developments we might be able to plan for divers and disperse Information Systems of our time (Edwards, et al., 2007). Infrastructural studies recently have attracted many researchers to investigate large, distributed and complex ICT systems which go beyond “a proof of concept”, a “prototype” or an isolated “application” (Ribes & Finholt, 2007). What they mean by infrastructure varies but is complementary and the objective is clear. They attempt to redefine the notion of “Infrastructure” “in favor of a more flexible and complex notion better suited for analyzing the role of information technology in information society” (Dahlbom, 2000, p. 213). To think of ICT systems as sort of “infrastructure” is justified for two reasons:

- Firstly, “information handling in many areas has shifted decisively from individual computers and local networks to more distributed grid or cloud paradigms dependent on ubiquitous links to and through the global Internet” (Edwards, et al., 2009, p. 365)
- Secondly, “digital convergence is rapidly integrating most media, melding data processing and text editing with audio, video, and images” (ibid, p.365)

It features a phenomena which with “robust, reliable, widely accessible systems and services” (Edwards, et al., 2009, p. 366) resembles other public infrastructures that we know traditionally such as railways and water supplies.
2.3.1. Other than System

Perhaps notion of “system” would be a good departure point from STS literature to understand the infrastructures. Wajcman (2002) describes the concepts of “system” within social studies of science and technology (STS):

“The idea of a technological ‘system’ or ‘network’ has been key. Although technological innovation crucially builds on previous technology, it does so not in the form of separate, isolated devices but as part of a whole, as part of a system. An automatic washing machine, say, can work only if integrated into systems of electricity supply, water supply and drainage. A missile, to take another example, is itself part of an ordered system of component parts – warhead, guidance, control, propulsion – and also part of a wider system of launch equipment and command and control networks. The need for a part to integrate into the whole imposes major constraints on how that part should be designed. A technological system is never merely technical: its real-world functioning has technical, economic, organizational, political, and even cultural elements.” (Wajcman, 2002, pp. 351-352)

This definition of “system” holds dependency characteristic on other systems and social as well as technical path. This standpoint criticizes the profit driven understanding of technology which would see the selection of technology is merely based on maximum profit (Wajcman, 2002). However notion of “system” has its limitations within the literature in term of its ability to represent this interdependency and perhaps can be interchanged by notion of “network” in that sense (Hanseth, 2002).

2.3.2. Learning from Public Infrastructure

Public infrastructures (e.g. water supplies, electric supplies, railways) are part of our modern life (Misa, 2003). We are surrounded with quit number of huge ‘ready-to-use, completely transparent and often taken for granted” (Bygholm & Nyvang, 2009, p. 31) technologies such as mail service and most recently Internet (ibid, p. 31). By definition of Webster’s dictionary, as Ole Hanseth reports, infrastructure is:

“A sub-structure or underlying foundation esp., the basic installations and facilities on which the continuance and growth of a community, state, etc. depend as roads, schools, power plants, transportation and communication systems, etc.” (Hanseth, 2000, p. 56)

However these technological advances have not been there long ago. In early twentieth century in London, it is reported that there were “65 electrical utilities, 70 generating stations..., 49 different types of supply systems, 10 different frequencies” (Edwards, et al., 2009, p. 366). This is different now and we have more standardized electric supplies. Nowadays, even though electric supplies may differ in certain details like AC Plugs from one country to another, i.e. not fully universal, but hardly we notice the differences. Electric supplies have become standardized and widespread so that we do not bother to know much about them in details. In another words the key question is always to ask “how big, or deep, or old, or widespread does something have to get before it becomes infrastructure?” (Edwards, et al., 2009, p. 366). So “a crucial aspect of infrastructural development is the design and diffusion of standards” (Hanseth, 2000, p. 61).

Another aspect of the public infrastructure is their social relationships. These technologies “interact deeply with society and culture” and this interaction “involves
mutual influences, substantial uncertainty, and historical ambiguity, eliciting resistance, accommodations, acceptance, and even enthusiasm” (Misa, 2003, p. 3). P.N. Edward argues that Infrastructures are “sociotechnical in nature” and are referred as infrastructure, not only for their hardware characteristics but also for “socially communicated background knowledge, general acceptance and reliance and near-ubiquitous accessibility” (Edwards, 2003, p. 188).

2.3.3. Information Infrastructure

What we mean by information systems matters. There have been several ways which discuss information systems as “artefact “,” the programming language”, “the overall architecture” or a “media for communication” (Monteiro & Hanseth, 1995). In this thesis I go through two set of characteristics of infrastructural perspective to information system. Both bring new insight into the discussion with different emphasis on technical, by Hanseth, and on use and practice, by Star and Ruhleder (Bygholm & Nyvang, 2009, p. 31).

Here I review the definition from Ole Hanseth (Hanseth, 2000; 2002) which extend the notion of system and network and opposes managerial point of view which focuses profit.

Hanseth’s list of characteristics includes two groups, first (enabling, shared, evolving and openness) (Hanseth, 2002; 2000), which are important for traditional public infrastructures and second (heterogeneous and connected) are those that “make IT infrastructure different from traditional information systems” (Hanseth, 2000, p. 56).

Infrastructures, including traditional public infrastructures, are “enabling” in the sense that they “support a wide range of activities” and, as a technology, is “intended to open up a field of new activities” (ibid, p.56-57). Infrastructures are more than “one way of working within a specific application field” (ibid, p.57). Even though the infrastructures are limited to certain set of functions but they have deeper “ecological” effect and they are much more engaged.

Another characteristic is being “shared” among a community or communities. Infrastructure is the “same object” which is used by all the members of the community, even though “it may appear differently” (Hanseth, 2000, p. 57). An application by joining to other applications can be used by larger number of members as “shared resource” and turns to an infrastructure which supports number of different activities (Hanseth, 2002).

Infrastructures are evolving, i.e. extended, improved and growing, continuously over the time in order to integrate more and adapt new applications (Hanseth, 2002). This evolution and integrations is happening through “standardized interfaces” which crucial for becoming an infrastructure (Hanseth, 2000, p. 57). For example a new speed-train with totally new high-tech features should follow old railroad standards; otherwise it cannot be connected to the existing railroad system.

Openness comes along the evolving and shared characteristics. It means an infrastructure is open regarding “to who can participate in the design, implementation and use of the technology” (Hanseth, 2002). Also it is open to any number of elements, such as application, which can be added to infrastructure. Such openness can be found in the Clinton-Gore report, “Electronic Superhighway”, which suggests inclusion of any equipment, information, application, standards and people (Hanseth, 2000, p. 58).
In addition Hanseth explains that this does not mean to take an extreme position toward being open but it is to emphasize that no strict line can be drawn around an infrastructure.

In the second group in Hanseth’s list of infrastructure characteristics, we find “heterogeneous” in two ways. Firstly, infrastructures are “socio-technical”, i.e. include technology, human, organizations and etc. Infrastructures simply cannot function if they are not supported by staff or not used by users (Hanseth, 2000, p. 59). Secondly, infrastructures are connected, layered upon each other, logically related, integrated by components and interdependent (ibid, p.59). The new IPv6 protocols in Internet and its relationship with older version of IPv4 is an example of this “ecologies of infrastructures” (ibid, p.59).

Finally infrastructures, as Hanseth summarizes, are “installed base”. This means that when they are developed, they are built upon other infrastructures and standards. As an “Infrastructure”, standards become backbone of IT (Monteiro & Hanseth, 1995). For instance, Internet has been built upon many previously successful standards (Hanseth, et al., 2012). These standards “are not ready-made, they are currently being shaped through complex, social processes” (Monteiro & Hanseth, 1995, p. 3) and “are nothing but neutral: buried deep in "technical" details they inscribe anticipations of individual, organizational and inter-organizational behavior” (ibid, p.3). As a result, Infrastructures are “part of human organization” (Star, 1999, p. 380) and socially constructed.

To summarize Hanseth’s point of view, “an infrastructure is an evolving shared, open, and heterogeneous installed base.” (Hanseth, 2000, p. 60). Hanseth’s definition is useful, firstly to differentiate an infrastructure from isolated applications or systems and, secondly to approach an ICT system in different way as is treated in managerial approach and having better understanding of the development of complex ICT systems. In particular he analyses the economy of ICT system under the notion of infrastructure.

Based on his definition, he suggests “positive feedback” from the growth of an infrastructure helps to extend it and its standards. It looks like a successful production in which “the more a particular product is produced, sold and used, the more valuable and profitable it becomes” (Hanseth, 2000, p. 61). This is particularly a characteristic of information and ICT products and it economy. He suggests Microsoft and its success as a clear example. In addition, the growing network provides a value proposition for the infrastructure. However there are some who are left out. This network is connected and affected by other networks, as Microsoft is connected to Open Source market and they do affect each other. An infrastructure is dependent on its previous standards, like strong dependency of Microsoft on existing standards used for C/C++ languages. Finally, one cannot change to another infrastructure easily, like many companies which would cost them a fortune to switch from Microsoft products and systems to something else.
2.3.4. Hooking Up to the Infrastructure

The second definition of infrastructure is given by Start and Ruhleder (1996) with focus on use and the practices. In this section I will review their definition.

2.3.4.1. Relational Property and Pragmatic Turn

Identical and useful aspect of Start and Ruhleder (1996) definitions has been the relational understanding of infrastructure. In their pragmatic understanding of infrastructure, to become an infrastructure is matter of situation and/or person, as they quote:

“We hold that infrastructure is a fundamentally relational concept. It becomes infrastructure in relation to organized practices. Within a given cultural context, the cook considers the water system a piece of working infrastructure integral to making dinner; for the city planner, it becomes a variable in a complex equation.” (Star & Ruhleder, 1996, p. 113)

In this approach “the design and use of Information System (IS) involves linking experience gained in one time and place with that gained in another, via representations of some sort” (Bowker & Star, 1999, p. 290). This experience is under influence of “people’s definition of situation” which “shapes their behavior” toward the systems.

According to Star and Bowker (1999), they learn from the pragmatic turn in which “what matters about an argument is who, under what conditions, takes it to be true” (ibid, 289). They take a broad view upon the origin of definition of situation. This view includes “human or nonhuman, structure or process, group or individual” (ibid, 290), and “materiality of anything (action, idea, definition, hammer, gun, or school grade) is drawn from the consequences of its situation” (ibid, 290).

2.3.4.2. Historical Analysis and Infrastructural Inversion as Methodology

Reading the past and the related narratives can help us to find out about “relational aspects” of systems. Within infrastructural studies the past and the history plays important role for their rich descriptions (Bowker & Star, 1999). They use rich description of the past and archeological approach to inform the analytics (Star & Bowker, 2006). For instance, Star and Bowker’s study (1999, p. 5) follows Michael Foucault in suggesting an “archeological dig” to elaborate the origins and consequences of those classifications and practices. This also provides details about relations which could open up into the mysterious world of ICT development, mostly through ethnographical researches (Star, 1999). In the historical analysis of an artefact “the politics, voice and authorship embedded in the systems are revealed—not as engines of change, but as articulated components of the system under examination. Substrate becomes substance.” (Star & Ruhleder, 1996, p. 113)

By “infrastructural Inversion” once suggested by Bowker (1994), they mean to unearth the interwoven relations in the field by historical investigation. This method “de-emphasizes things or people as simply causal factors in the development of such systems; rather, changes in infrastructural relations become central” (Star & Ruhleder, 1996, p. 113).

Bowker (1994) has studied an oil discovery company which starts by a discovery of a scientific innovation. The innovation helped to realize when an oil well hits the
underground water. This was particularly important for the companies to have this information to reduce tremendous costs of drilling by increasing number of successful drillings. A series of interconnected facts and strategies help to fit the innovation in form of one of the biggest oil exploration companies. For example in his study, the company emphasizes to keep the mythical appearance of their exploration by adding extra keys to their instruments and also secretive act of engineers. In this way the uncertainty is hidden and the mystery of the work is well kept while the company could learn more and perform more experiments by getting more projects. Another example was building clocks in the cities across which they had their projects. This played an important role in the contracts and the legal battles.

I can summarize the methodological framework followed by Bowker and Star in four elements: “

- A historical process of development of many tools, arranged for a wide variety of users, and made to work in concert
- A practical match among routines of work practices, technology, and wider scale organizational and technical resources
- A rich set of negotiated compromises ranging from epistemology to data entry that are both available and transparent to communities of users
- A negotiated order in which all of the above, recursively, can function together” (Bowker & Star, 1999, p. 34)

2.3.4.3. **Infrastructure Dimensions**

Earlier I reviewed infrastructural dimensions from Hanseth’s point of view; a shared, enabling, evolving and heterogeneous installed base. Similarly, Star and Ruhleder (1996) suggest list of dimensions for infrastructure, adding the relational property. They believe that “the configuration of these dimensions forms “an infrastructure, which is without absolute boundary on a priori definition” (ibid, p.113). Again the emphasis on no “absolute boundary” and “priori definition” resembles Hanseth’s understanding of infrastructure as an “open” artefact, which explained previously.

In Start and Ruhleder point of view, an infrastructure is an embedded and transparency artefact with great reach to its members which are linked to the artefact by conventions of practices. They see it as “embodiment of standards” which is built upon other body of standards (Star & Ruhleder, 1996, p. 113).

Their list is very close to Hanseth’s list of characteristics as shared, enabling, evolving and heterogeneous installed base (Hanseth, 2000). However they add and emphasize that infrastructure has no value without user and it is a relational concept.

2.3.4.4. **Three Group of Use Issues in an Infrastructure**

The Star and Rudeler (1996) study presents analysis on type of user issues. Despite the well-developed system, these issues have made the users to prefer Internet or to find other ways instead of the developed system.

First group of issues “center around the installation and use of the system, and include finding out about it, figuring out how to install it, and making different pieces of software work together” (Star & Ruhleder, 1996, p. 118). For example, to install a new
application we may have to purchase and change our PC’s screens to be able to handle proper image resolution. Then our first problem will be to purchase the required screen. These issues are continued to remain because of changes and new stages of system updates, e.g. new tools or applications (ibid, p.118). As long as we use certain application, we will have to keep eye on providing proper hardware as we did for the screen. Although more money, time or resource would be the solution; they may mix with other level of issues or shift to different level of issues because of their relationship to other elements, such as standards of system components and organizational dependencies to purchase (ibid, p.120). This means the issue gets more complicated if because of our company rules and regulations we have to purchase certain size or we are limited to certain budget which is controlled by another department. So the first order issue, a simple act of purchase, shifts to more complex issues.

The second group of issues are about contextual differences or collision of several first order issues (ibid, 120). Simple cultural difference can create big problems and gaps among the parties. Start and Ruhleder report the difficulties of getting biologists to accept and work with UNIX base Worm Community System (WCS) (ibid, p.120). In their case some extra knowledge of one practitioner has been helpful to cover the gaps among the Mac and UNIX systems. This means different level of knowledge, money or other resources would affect the use issues. Another example is the “deadline” which is constraint and also resource depending on different users (ibid, p.122). Many deadlines for some people have been troublesome and no deadline sometimes meant that the work will not be done. For this group of issues more money or other resources would be helpful. However when the resources are not enough so then the question rises that which problem to address first (ibid, p.123); and this is the third level of issues.

The third group of issues is about selecting among the “second-order alternatives” (ibid, 123). This refers to the “problem-solving” among various conflicting heterogeneous communities. Scientific communities are the examples which Star and Ruhleder research. Basically the system itself or the data can mean different thing for different communities. What matters for one community it may not be right for others and even in one community overtime things may change without proper referencing. Finally, when the system is in place, those who have not been “hooked-up” to the system will suffer and will be left out, as a negative effect of “network-externalities” (ibid, p.124). The third group of issues requires larger coalition to find proper solution for these complex problems.
2.4. Theoretical Convergence in Information Infrastructure

In this section I discuss the relevancy and role of the described theories about information infrastructure. I attempt to reflect on the theories within my knowledge and its relevancy to the thesis.

Firstly I should mention that by convergence in the title of this section I do not mean to propose clear convergence between various theories which were explained earlier. However there are concepts where those theories agree upon and in my opinion these theories are rather complementary to each other. For example, infrastructural studies share great deal of SCOT point of view and STS socio-technical approach to the technology, in our case to ICT. Also what Star and Ruhleder (1996) discusses in Cyberinfrastructure, are deeply aligned with STS studies like Hanseth’s researches.

I have discussed mainly SCOT, Ole Hanseth’s definition of information infrastructure and theories from Star and her colleagues. The arrangement in the thesis follows partly their historical sequences as well as their use in the thesis.

SCOT is applying EPOR’s approach and the concepts can be applied for technology in general term. It shows the role of people and their perceptions in creating the artefacts. Based on SCOT, variety of perceptions provide flexibility in choices and at least “in principle, everything can be disputed, negotiated, or reinterpreted” (Hanseth, et al., 1996, p. 13).

Ole Hanseth’s and his colleagues see information infrastructure as an “aligned actor network” (Hanseth & Monteiro, 1998, p. 100). They build upon the flexibility and openness brought by SCOT and argue that this flexibility of information infrastructure is “hampered” by fast changing technology (Hanseth, Monteiro and Hatling, 1996). Furthermore this flexibility may be reduced due to the “irreversibility” which is the result of “inscription” of standards in information infrastructure and this provides better explanations for detailed functions (Hanseth & Monteiro, 1998). This idea is reflected in the concept of “installed base” which is explained earlier. The result becomes useful concept for information infrastructure where they call it as “cultivation” (ibid). So basically I discuss Hanseth’s definition as an introduction to Star’s work.

Finally Star and her colleagues describe information infrastructure with pragmatic approach. They assert similarly, to Ole Hanseth, accepts the rigidity aspect of information infrastructure but from “Structuration” theory and learning from Giden’s (Star & Ruhleider, 1996) where it is seen as a result of “tension between local, customized, intimate and flexible use on the one hand, and the need for standards and continuity on the other” (ibid, p.112). They do not emphasize either people and/or technology with their pragmatic approach. Their focus is on use where they assert information infrastructure becomes an infrastructure upon use and not only by existence of standards and/or network of technologies (ibid).

As we see in this section, the concerns of these theories are different. However they become complementary theories to each other. I think we would have better understanding of dimensions of infrastructure which are listed by Star and colleagues by reading Ole Hanseth and his colleagues’ literature. In fact the latter is one of the foundations of the Star and her colleagues’ studies. Star and colleagues in addition, provide more analytics for use issues that help me to answer the research questions.
2.5. ICT for Learners

In this section I will discuss the literature for ICT intervention in learning environments, particularly Computer Supported Collaborative Learning (CSCL) as the precedent of Technology Enhanced Learning (TEL) literature. Use of ICT for learning is investigated under variety of terms such as CSCL, e-learning, m-learning (Mobile Learning) and TEL. It may not be easy to draw a proper line between all these fields. However TEL is inclusive of all sorts of technologies, design, computational, cognitive, social and epistemological areas (Balacheff, et al., 2009). Therefore I will start with rather influential CSCL and continue with TEL whereas many aspects are converging.

2.5.1. Computer Supported Collaborative Learning (CSCL)

Despite the laymen understanding of “Collaboration”, there are vast definitions and interpretations of “Collaboration” among scholars. This becomes more of chaos when another controversial word is attached to it such as “Learning”. In the research program “Learning in Human and Machines” conducted by group of scientists, the word “Collaboration” has proven to be a controversial concept (Dillenbourg, 1999). The word which looks easy at the beginning is understood in various ways and meanings. One factor in these definitions is the scale of collaborative situation in size and time. The next obstacle is collaboration itself and the question that “What is Collaboration?”

The situation can vary from one to one situation to situation of 40 groups and subjects, from 1 hour to years of interaction (Dillenbourg, 1999, p. 2). This plays important role when subsequently other joint concepts are derived such as learning, co-constructing common language and etc. What is noticeable discussion in the scale is the unit of analyses that can elaborate the situation.

As Dillenbourg (Dillenbourg, 1999) asserts we are dealing with different aspects of learning in “Collaborative Learning”. To achieve collaborative situation, it is stated in literature that (i) peers should be in same level (symmetry either in action, knowledge or status in community) (ii) have common goals and (iii) work together. Interaction among the learners also is taken as collaboration. Effective interaction, synchronous communication and negotiability are named as characteristics of collaborative interactions. Several mechanisms also are studied in individual level of learning collaboration. Finally the effects of the collaborations are studied in different ways.

Learning itself is another controversial concept (Dillenbourg, 1999). In some extend activities in “educational context” including studying course materials are considered learning. Problem solving also widely referred as activity which learning is the side-effect. For other is a developmental biological or cultural process or even acquisition of expertise from professional communities (Dillenbourg, 1999).

Therefore it is no easy task for CSCL researchers to deal with this discourse. As a result, CSCL inherits wide range of units of analysis of collaborative learning (in term of scale) and different forms of collaborations and learning using different set of ICT systems. It covers interaction of two people within 30 minutes to several thousands of people over several years (Dillenbourg, Järvelä and Fischer, 2009). It includes discussion of socio-cognitive theories for small scale to socio-cultural theories for large scale collaborations (ibid). Accordingly different methodologies are applied including quantitative methods for small scales to qualitative ethnographical methods in large scale collaborations (ibid).
CSCL has evolved like other ICT research areas over years of ICT evolution. Dillenbourg, et al. identifies three ages for CSCL and suggests that the collaboration in the learning is integrated in a comprehensive environment of non-collaborative activities and the recent years sees the decline of CSCL, replacing more comprehensive approaches (ibid).

2.5.2. Technology-Enhanced Learning (TEL)

According to TEL literature ubiquity has effect on learning environments. The more “ubiquitous” technology emerge, the more “boundary between computer supported collaboration and other forms of collaborations is vanishing” (Dillenbourg, Järvelä and Fischer, 2009, p. 12). With current ubiquitous technologies and technological advances, learning environments are integrated more in various “social level” (e.g. individual and group), across different “contexts” (e.g. classroom, home or field trips) and “media” (e.g. with or without computers, video) (Dillenbourg, Järvelä and Fischer, 2009, p. 12). So TEL is about integration, convergence and ubiquity of technology in our time in learning process.

2.5.3. ICT Development for Learners

Moving further, the technological advances are seen more related to the activities and practices. This short review is discussing this relevancy.

Dillenbourg and others recently have developed the notion of “Orchestration” as “the process of productively coordinating supportive interventions across multiple learning activities occurring at multiple social levels” (Dillenbourg, Järvelä and Fischer, 2009, p. 12). Even though Dillenbourg limits this definition later on to classroom (Dillenbourg, 2013), he sees the “Orchestration” as “form of management” among various “integrated scenarios” (Dillenbourg, 2013). Under this notion, CSCL may disappear, since “collaborative activities” are integrated in “comprehensive environments” with “non-collaborative activities” over “digital and physical spaces” (Dillenbourg, Järvelä and Fischer, 2009, p. 4) and “boundary between computer supported collaboration and other forms of collaborations is vanishing” (ibid, p. 12).

The purpose of this conceptualization is minimalistic approach on relationship between research and practice and also search on ways to “design” “usable and useful” tools for realistic learning environments (Dillenbourg, 2013)

This is no surprise after two decades of researches; we come to the key lesson from CSCL that:

“Collaboration can be “designed”, and team processes shaped by the software tools used by the teams” (Huang, et al., 2009, p. 6).
2.6. Cyberinfrastructure Development

Some researchers suggest that science is an “inherently collaborative enterprise” (Finholt, 2002, p. 73). This approach has triggered series of researches that have applied concept of Infrastructure to study a wide range of systems and applications which are developed for scientific researches and laboratories.

In this section I will look into collaboratories in science and Infrastructural studies in e-science and Cyberinfrastructure (CI) in brief. In addition I will present the framework which is meant to be used in the thesis.

Collaboratories play an important role in the contemporary science history and the history of use and application of ICT in science. In collaboratories we can see historical sites of ICT projects with several layers of interrelated setups.

A collaboratory as Finholt & Olson defines “is a computer-supported system that allows scientists to work with each other, facilities, and databases without regard to geographical location” (Finholt & Olson, 1997, p. 28). Scientists have been the earliest adopters and promoters of ICT which disperse collaborations use, including World Wide Web (Bos, et al., 2007).

Several ICT projects are considered as collaboratories in recent decades and have had huge impact on future of science and researches, like WATERS (Water and Environmental Research Systems) (Ribes & Finholt, 2007) or BIRN (Biomedical Informatics Research Network) (Lee, Dourish and Mark, 2006).

There are many types of collaborations and ICT systems in these collaboratories. In one research (Bos, et al., 2007) seven categories of collaboratories’ type are described: Distributed Research Centers, Shared Instruments, Community Data Systems, Open Community Contribution Systems, Virtual Communities of Practice, Virtual Learning Communities and Community Infrastructure Projects (Bos, et al., 2007).

Recent years there have been many researches regarding the development of Information Infrastructures for scientific collaborations and researches e.g. (Lee, Dourish and Mark, 2006; Ribes & Finholt, 2007; Ribes & Finholt, 2009; Bietz, Baumer and Lee, 2010). These studies investigate challenges and tensions which provide useful concepts to analyze infrastructural developments. Lee et al. (2012) , for example, identifies some aspects of infrastructural development like role of socio-technical resources in resolving sustainability issues.

One of the comprehensive frameworks is suggested by Zimmerman. Zimmerman (2007) suggests a socio-technical framework (figure 4).

Each element in her framework can be seen like an axis which is by Zimmerman’s experience every cyberinfrastructure (CI) can locate itself in that axis. She asserts that this axis is not intended to show how good or how bad the situation for certain CI is. Her idea is to illustrate the range of CIs which exist. For instance CI can range in sense of maturity from a fully working CI to a CI which is in its early stage of system documentation. Depending on which stage a CI is, it may face different tensions, such as duality, as a development project or a research project.

This framework includes few elements grouped under two major characteristics, characteristics of the infrastructure and characteristics of users. Characteristics of the infrastructure consists of two elements, maturity and complexity. Characteristics of users includes capabilities of users, users’ expectations and perceived needs by users. Also three other elements are added to illustrate the whole picture of CI development,
hardware and software in CI development, role of other stakeholders and mechanism for feedback and coordination.

Figure 4 Zimmerman’s framework (2007)
2.7. Use of Theory


- As an initial guide to design and data collection
- As part of an iterative process of data collection and analysis
- As a final product of the research

Learning from Walsham’s research (1993), in this thesis I take part of the theory sections as the initial guide to the research design and data collection. The social process from SCOT and Infrastructural inversion from infrastructural studies requires a qualitative study. SCOT questions the social groups, their activities while Infrastructural Inversion investigates the history of the projects. As mentioned earlier the historical archeology approach to collect data from the development group is learned from those researches. The TEL development and research is seen as an information infrastructure and infrastructural development which is described by Star and her colleagues. Also their researches inform the methodology, the data collection and the interview questions of this thesis in quest of unknown issues.

On the other hand the SCOT concepts and terms help to interpret the data and provide meaningful analysis. Using those terminologies, concepts and frameworks I will answer the research questions. Identifying the relevant social group, their problems and their interpretation and their achievements are the way that SCOT suggests to see the reasons behind the success and/or failure of the technology in use. Star and Ruhleder’s (1996) classification on use issues from infrastructural analysis, provides the analytics to answer the second research question.

Furthermore after the analyses and discussions I compare my finding with an existing framework from other infrastructural studies, cyberinfrastructure studies. This is considered as the product of this study to suggest similar framework within TEL R&D.

Figure 5 is attempting to illustrate different parts of the thesis. I start to perceive TEL as an information infrastructure with a worldview from SCOT studies whereby technology is a result of a social process. Then as those theories requires, a qualitative research is designed with related methodology. Next step is to analyze the empirical data using both infrastructural and SCOT theories. The last step is to compare my findings in TEL R&D with existing infrastructural studies.
I believe in the advice that Walsham has about the selection of theory:

“So, my first piece of advice for new researchers is for them to choose theories which they feel are insightful to them.” (Walsham, 2006, p. 325)

For me, in fact the insight was earned during few month of exposure to the facts and theories around the TEL development and several times revision of the relevant information, papers and literature.
3. Methodology

In this section, methodological decisions will be discussed. Methodological logic “involves making coherent and reasoned connections between the choices”, “which methodological tradition to follow” and “which approach and which data collection methods” is used (Hart, 2005, p. 313). The methodological decisions are essential for scientific findings. Robson (2011) asserts a definition of “science”, quoting Johnson and Christensen:

“We define science as an approach for the generation of knowledge that places high regard for empirical data and follows certain norms and practices that develop over time because of their usefulness”. (Robson, 2011, p. 14)

Robson emphasizes “scientific attitude” toward a research to seek the “truth”. A research should be done:

- Systematically: is about what is that the researcher is doing, why and how questions, including “nature of the observation”, “circumstances in which they are made” and the role of the researcher (Robson, 2011, p. 15)
- Skeptically: openness to “disconfirmation” by researcher or others about whole of the research (ibid, p.15)
- Ethically: following “a code of conduct” which would save the interests are participants and those who are affected (ibid, p.15)

I start this section with reflection on Information System (IS) research and I will describe the approach, method, data collection, data analysis and ethical concerns.

3.1. Information System (IS) Research and Methodological Pluralism

The current literatures which I have been reading are filled with various kinds of complexities, more specifically complexities caused by relationships among digital and physical world and also technical and sociological aspects of technology. Walsham (2012) discusses the difficulties that Information System (IS) field is facing to cope with the changes of ICT presence in our life and compare to the niche stand point that IS had years ago. He advises the IS scholars to keep IS an open boundary field and to consider methodological pluralism. Another advice of Walsham is to have critical position in order to make a better world with ICT.

Following Walsham advices in this thesis I approach TEL as infrastructural development rather single software solution development and as social-technical development rather than technological advances. This leads me through understanding the whole development cycle as socially related to various ideas and as social process rather than technical creativity and enhancement. In order to understand this social process I will need to understand related social groups and their relationship in the sample development group.
3.2. Research Approach and World View

There are immediate implications in thinking of IT as an infrastructure. These implications are drawn from STS and SCOT and their world view. In this section I will illustrate the world view and research approaches which we would take upon considering ICT system development as an infrastructural development.

To seek a proper approach to the complexities in the real world with great technological advances, it would be useful to return to the early discussions of technology studies and social studies on the late years of twentieth century.

According to Pinch and Bijker (1984) technology studies gain more popularity in the late years of last century. Technology studies are trying to open the “black box” of technology and investigate the relationship of science and technology (ibid). The shift has been from understanding of technology as a pure application of science to an intermixed picture of both whereby both are able to generate facts and both are equally socially constructed (ibid, p.403). I shall quote Barnes’s words (1982 cited in Pinch and Bijker, 1984, p.403), for further clarification:

“I start with the major reorientation in our thinking about the science-technology relationship which has occurred in recent years ... We recognize science and technology to be on a par with each other. Both sets of practitioners creatively extend and develop their existing culture; but both also take up and exploit some part of the culture of the other ... they are in fact enmeshed in a symbiotic relationship” (Pinch & Bijker, 1984, p. 403)

This social constructivist view of science and technology is an emerging view since then. Pinch and Bijker (1984, p. 408) believe that “the only effective way to deal with” various difficulties in explaining “good technology” and its relationship with scientific facts “is to adopt a perspective which attempts to show that technology, as well as science, can be understood as a social construct” (ibid, p. 408). In this way we may have fewer problems to justify success of a technology which is based on false scientific facts or similarly upon the failures of technology. So applying a technology is more than a highly advance technology and is dependent on understanding of several social groups and their use of technology.

The social constructivism view of technology is traditionally interpretivism upon empirical studies (Pinch & Bijker, 1984, p. 409). Interpretivism is an approach in which researcher interprets, understands and explains, relative truth/falsity, of subjective nature of human behavior (Hart, 2005, p. 194). This approach may consider sometime interpretation of individuals rather than groups in the way they “make sense of their world” (Robson, 2011, p. 24) and sometimes it is referred as interpretivism to show the “focus on how the social world is interpreted by those involved in it” (ibid, p.24). The related social groups in TEL development have different interpretations which has direct effect on the success of the technology developed for educational purposes.

3.3. Qualitative Research

In line with the thesis’ approach, interpretivism and social constructivism, which discussed earlier, the thesis is designed as a qualitative research. Qualitative research is identical in “little or no use of numerical data or statistical analysis” and also by inductive logic, focus on meanings and contextual inquiries (Robson, 2011, p. 19).
Despite the objective world of quantitative researches, researcher’s commitment, flexibility and reflexivity is appreciated (ibid, p.19).

For qualitative research, “generalizability of the findings is not a major concern” (ibid, p.19). However it does not mean that these researches are not able to generalize but they do not aim for it through formal statistical techniques (Hart, 2005, p. 182).

Infrastructural studies are considered qualitative studies in an ethnographic sense which is “an idea that people make meanings based on their circumstances, and that these meanings would be inscribed into their judgments about the built information environment” (Star, 1999, p. 383). These studies are supposed to reveal “the unstudied” per se “the forgotten”, “the background” and “the frozen in place” (Star, 1999, p. 379).

I should mention that due to the limitation in time and resource, I do not conduct an ethnographical research in this thesis. However I make use of the insight given by this methodology. It means while I avoid an ethnographical research methodology I do ask about their detailed experience of TEL development to reach to “the unstudied” and to shed light on “the forgotten” aspects of their work.

In this thesis I read the Technology Enhanced Learning (TEL) as “a material artifact constructed by people, with physical properties and pragmatic properties in its effects on human organization.” (Star, 1999, p. 387) This is to reach to interpretations of the various social groups and human organizations within TEL development with a belief that their understandings has direct effect on the outcome of the technical development.

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This qualitative research is conducted upon a research and development center. This provides the chance to have the participants’ understanding of reality and add to our knowledge of their actions (Baxter & Jack, 2008). The reasons to use a TEL development center in this thesis, as learning from ethnographical insight and not as ethnographical as method in this thesis, following Baxter & Jack (2008), are:

a) The thesis’s concern is about “How” the TEL technologies came to existence and “Why” they are underused
b) The TEL researchers and intense activities would not be manipulated easily by me as researcher
c) The contextual conditions have direct effect on TEL research and developments
d) It is hard to imagine the TEL researchers without their researches and projects

One of the important achievements targeted by this method is the “installed base” characteristics of the infrastructural understanding. It means understanding the existing technical advances, technical knowledge and systems, the setup and policies and human organizations have crucial role in determining the outcome of the TEL products and their use. Without this profound understanding the TEL projects are seen as singled out and isolated applications which has no relationship with long historical background. In this way we are losing the bigger picture of the whole TEL development.

3.4. Description on TEL Development Center

This thesis is investigating a research and development and development center in Sweden which have conducted several research projects, TEL related, for more than 10 years. I intentionally keep the center anonymous as much as I can. This is because of the anonymity of the interviewees. Since the center has very limited researchers and
revealing the center’s name would be kind of revealing the identity of the participants. I am aware that the range of the information which I provide may reveal the center’s identity. However this is not intentional.

The group has strong relationships with other research centers and universities in Europe, US and Middle East. It is a well-known center in TEL research and benefits from participation of leading researchers in TEL.

Beside the multinational environment in the center, the scholars and students from different countries, the center enjoys very friendly and cooperative relationships among the members. I personally, during my interaction with the members, witnessed very positive comments about members’ knowledge, personalities and research activities and attitudes. The center also has succeeded in the academic environment with numerous publications, providing invaluable knowledge in the domain, preparing the next generation of researchers.

The center has worked on several projects which two were most mentioned in the interviews. It is also my own observation from the papers published by center that these two projects have been fruitful projects for the center and also presenting the R&D activities of the center. Hence I take the two projects as an example about their research and development activities.

These two projects, named as X and Y in this thesis included other sub projects during 5 to 7 years of research. Project X, conducted for seven years, the project is looking at the technologies which make the mix, indoor and outdoor, educational scenarios possible. Project Y, conducted for five years, brings computing technologies to outside classroom and is trying to extend the interaction with physical world. Both projects are supported with the center and its alleys in other national and international centers and universities.

In both projects mobile technology, advance communication and collaboration have been the major concerns of the researchers. In project X contextual information plays important role and it is important for the researchers to look into the different educational environments. In brief the project X is using mobile ICT for collaborative learning, suggesting conceptual framework for mobile learning design and adding contextual information. In project Y new ways of interactions for experimental purpose is emphasized.

During last ten years the center has developed internal systems and tool which help them to conduct their research in different ways and to be the base of the future projects. Many of the members have been in center for several years in different roles. This has created certain way of workplace habits, if not culture. I will come back to this shortly in the interview results in more detail.

These characteristics make the center a unique case which the TEL research is conducted and develops the infrastructure which may have great impact in the body of the domain and also in the society. So for that very reason this research hopes that can illustrate some of the challenges and become helpful, even though considering the all limits of this research in knowledge and skills.
3.5. Role of Researcher

I believe that “the task of researcher is to understand the multiple social constructions of meaning and knowledge.” (Robson, 2011, p. 24)

Nevertheless the theory and the method of study of this thesis made me live with the ideas for few months so that I could read many articles around the topic, attend the seminar by the same research group and read their publications even though I could not present them as my research empirical. It means that I had to observe and get the sense of their environment and the data I had at the same time I was having different understanding of the theory itself.

This study was like journey for me whereby I passed through various theories and ideas. But still attempting to answer the very first question for me on ICT when it should serve certain practices among sort of communities, how it is done and how it should be done. Among the closest communities was the research center which I selected for my thesis. So while I was reading through various theories I started to learn about the TEL development center, its publications, type of their researches and activities. Finally I selected the theories and I drafted the interview questions. The interview sessions were set with the members and I was able to conduct successfully the qualitative data from the participants. I was reading through the literature between the data collection and after that even though it took sometimes for me to make sense of those theories which I used for data analyses (i.e. SCOT). I managed to compare the findings with existing results with similar literature (i.e. CI).

3.6. Data Collection

In this thesis, like some of infrastructural studies (Bowker, 1994; Bowker & Star, 1999), I have applied the “infrastructural inversion” technique that was explained earlier. This involves a historical analysis of an artefact which “the politics, voice and authorship embedded in the systems are revealed—not as engines of change, but as articulated components of the system under examination. Substrate becomes substance.” (Star & Ruhleder, 1996, p. 113). Also the ethno methodological sense and archeological approach, learned from studies like (Star & Ruhleder, 1996), required me to observe and learn about the research center and the related researches which helped me in designing the interviews, the interview questions and conducting the interviews.

In order to conduct the historical investigation I have used firsthand information from the researchers who were involved in the researches for at least one year and they have been closely engaged with the projects and the R&D activities. This has been again a purposely selected strategy in order to fill the requirements of the research design.

In this way I follow Bowker’s (1994) research which relies on the storylines of the company to argue that “industrial science and technology is consequent on and reflective of a new way of working, that its true filiations is not with the mythology of great scientists but with the might of the industrial revolution.” (Bowker, 1994, p. 14). His argument is based on the illustration of relationships between infrastructural work (i.e. the set of administrative, social and technical techniques) and the company’s
industrial science, also the relationship between the work on the field and the representation of the work in public.

One of the key elements of his argument is drawn from the way he reads the history of the company. Bowker explains that why he approaches the first hand sources of the company, instead of scientific or industrial reports. He challenges both pure academic and industrial science in the way they report their achievements. He asserts from Latour (1987) that “in both industrial and academic science there is a process of destroying the past” (Bowker, 1994, p. 16)

Bowker has provided an example to show how the facts are factored from academic and industrial documents. Below are two versions of storytelling about the incident which Schlumberger got his first idea about the How to locate the oil without digging the earth.

“A: On a cold winter’s morning in 1911, Conrad Schlumberger performed some experiments in the Ecole des Mines in a converted bathtub that had been used by his daughter. These experiments indicated that one could locate hidden meal in the copper bathtubs.

B: Conrad Schlumberger proved that ore deposits could be located by charting lines of equi-resistivity at the surface of the ground.” (Bowker, 1994, p. 16)

B is the version of A which comes in the scientific papers. The details are taken away to keep scientific rigor. Bowker believes that both academic and industrial science destroy historical context for their own reasons, one because of rival company and another one because of citation. Bowker acknowledges these issues and attempts to rely on more original sources.

In case of my thesis, since I had no access to the original written sources, so I have conducted the interviews with the researchers to have the storylines. As a qualitative study, I am using semi-structured interviews to collect the main part of my empirical.

3.6.1. Interviews and Participants

According to Robson, “the research participants are viewed as helping to construct the ‘reality’ with the researchers.” (Robson, 2011, p. 24). I have selected the researchers of the selected research group as source of my empirical. To request the interviews I used the official website of the group to have their names, contacts and some information about their research interests. So I select 15 researchers who had participated in TEL projects of the group and I contacted them through their email address. I was able to have 6 appointments directly. While I was conducting the interviews two of the interviewees recommended one of the researchers so I emailed again later on and I was able to book an appointment. So I have interviewed 7 researcher whom I will refer with alphabetical order in the empirical and analysis as R1 to R7.

All the researchers had been engaged with the group R&D activities for at least one year at the time of interview. Most of them had 3 years or more experience with the group. Even though the interviewees were from wide range of experience and also different backgrounds (i.e. from one to ten years having experience in the center, with background of pure computer science research or mixed background from other
disciplines), it was not the aim of the research and it was not intentional to do so. However it helped to gather data from different point of view.

I had emailed the 10 interview questions before the interview so the interviewees had clear idea what would be the questions. The interviews took from 29 minutes to 64 minutes, depending the willingness of the interviewees and the provided information. All the interviews conducted by according to the convenience of the interviewees and there was no obligation in place or time. Also the consent form is signed by interviewees to assure the privacy and have their permission to record and publish the results autonomously for the purpose of this thesis.

3.6.2. Interview Questions

During my exposure to the theoretical discussions and literature of infrastructural studies, I noticed the type of questions which are asked explicitly or those guiding questions by researchers’ personal interests. The questions were an archeological dig, such as (Bowker, 1994), a trip to the past by the words of participants, like (Lee, et al., 2006). Also always the narratives given, written or recorded were very original stories from the field, (Bowker, 1994; Bietz, Paine and Lee, 2013; Bietz, Baumer and Lee, 2010).

For this reason I tried to take the participants to the past and try to get as much as narratives I could. Even though I have not been able to conduct the interviews like the experts, however I was able get very close and first hand narratives which were telling about the important moments, incident and processes.

The questions are disclosed in Appendix 1. There are three types of questions. The first type (e.g. Question 1) of questions helped me to start with their exposure to the center, the way they had started their research in the center, their collaborations in center and their role. I needed to find out about number of roles involved and their interactions and their roles. These helped me to identify social groups and their understanding of TEL development.

The second types (e.g. Question 3) of questions are about the happenings and how the actual researches are conducted. Also I needed to learn more about the concepts, the terms and possible definitions in the center. How the important terms and concepts are defined and perceived gave me an overview of interpretation of the researchers of the artefact, based on SCOT’s interpretive flexibility. Also the existing setups, policies and technologies which they rely on were discussed in these questions.

The last group (e.g. Question 9) was to let them share the closures and contributions from their own and groups’ work while adding complementary points which I may have forgotten. With this part of questions about the achievements, challenges and additional points, I was trying to learn and figure out what is neglected by me and also possible stabilizations I the way that is suggested in SCOT.

I may not been able to cover all of their valuable works, however I hope this study is revealing important parts of the efforts and helps to draw a better path for future and bigger picture of the TEL development.
3.7. Data Analyses

The first step of my analysis started before collecting the empirical and while I was planning for interviews. To avoid forgetting the reason that why I choose a specific question, I took my own notes that why and for which purpose I have a certain question, transcribing main points. The major theoretical framework which I was using was the Star and her colleague’s researches on information infrastructures.

Walsham (2006) suggests noting impressions after the interviews. My first note and essay after the doing the interviews and first transcribing attempt, was an impression of the whole and what I could understand at that moment. Those notes were discussed with my supervisor and I took note every time I could make a link between the literature, the data and my own observations. As Walsham emphasized: “I believe that the researcher’s best tool for analysis is his or her own mind, supplemented by the minds of others when work and ideas are exposed to them” (Walsham, 2006, p. 325)

More organized form was only possible after I was exposed to SCOT concepts following the theories in which infrastructural studies are conducted. In this round the development process suggested by Pinch and Bijker (1984) was my guide to group the notes and storylines of the interviewees. In brief I was looking for the “relevant social groups” with their “interpretation” which took part in “stabilization” of any sort within R&D activities.

As a result I came to conclusion in term of those three concepts and starting to compare the findings in TEL with existing literature in infrastructural studies.

3.8. Validity and Reliability

Evaluating the research according to Plano Clark & Creswell (2010) “are essential part of the research process so studies and new knowledge are continually examined and critiqued by the larger community of researchers and practitioners interested in the studies’ topic” (ibid, p. 10)

Since this research was an individual research and thesis I have not had a full peer review. However most of thesis sections are reviewed and discussed by the first supervisor and also the second supervisor upon the resubmissions.

I have sent full description of the interviews, in two instances, to the interviewees in order to check the validity of the data.

As I mentioned earlier, the thesis is inspired with ethnographical researches. In such methodology whenever the direct observation or attendance is not possible, the researcher can rely on the information which is provided by the participants (Thomas, 1993). Since I was not able to participate in the actual TEL researches and developments, I had to rely on the observations of the actual researchers. Starting with review of the papers and publications of the center, attending their seminars in the university and interviewing 7 members of the center, all within a yearlong interaction, I have been spending, considerably, prolong time with the researched.

The data collection and data analysis are explained in details, so the research can be replicated by other researchers in same context.
3.9. Ethical Concerns

Work of research has never been an easy task, especially when the participants are scholars and professionals themselves. I had always the fear of revealing of the participants’ identity. I decided to code the participants as something like P1, P2, etc. So the chance of relating the quote to specific person would be minimized and I would be able to follow the analysis. However there is still a chance of knowing who said what. This dilemma perhaps unavoidable but can be approached cautiously to reduce the chance of revealing the identity of the participants.

To be able to record and use the comments for research purpose, I provided a consent form to agree upon the conditions of the interviews and the use of data (Appendix 2). Also I asked the interviewees whether they would like to verify the interviews and I sent them in case they liked to review.

One of the difficulties in interdisciplinary work is perhaps having different point of view about the researches, topics or methods. This made my job more sensitive when I encountered contradictory comments among the participants. As a result I do not name the research group in my thesis; in this way I keep the quotes and comments neutral as possible. This also helps me to avoid commenting the center while having its name on it.

Another issue has been drawing lines in my words so that the vocabularies do not misjudge a particular comment, approach or note. I have to avoid any statements which sound judgmental which may create misunderstanding for group of hard working scholars which for years have been pursuing great visions and have done tremendous effort to create better world. This is I think a pitfall for new researchers. I believe and I have tried to respect the work of the group while studying it.

3.10. Summary

In the methodology section I explained the qualitative and interpretivism worldview of the thesis. This is particularly important for my thesis to have such an approach in order to have proper insight to the broader understanding of the TEL development.

In order to achieve this world view the methods selections of interview as data collection method was outlined. Also inspired the designing the questions for the interview.

A brief description is provided for the interviewee’s groups and their development center which is one of the important TEL development centers in Europe.

In addition validation process and ethical concerns were discussed in order to provide more reliable results.

In the next section the empirical findings are presented using the above methodology.
4. Empirical Findings

In this section I will present the findings from the interview sessions with the researchers. Every question refers to the activity, material (digital or physical) and methods in the research practice. I will go through the answers of participants to every question. On each question there are replies and also discussions related to that question. Those discussions also are included under the same question even though they refer to other topics.

4.1. Interview Q/A

In total 7 researchers were interviewed ranging from 29 to 64 minute. All the interviews were conducted in the academic environment where the interviewees were comfortable with. In this section I will summarize the notes from R1 to R7 which refers to the interviewees in alphabetical order. The three themes were result of the nature of the questions and the answers also supported the idea even though the grouping is not in order by the form which was numbered and emailed to the interviewees. There were some extra questions to open a certain aspect during the interview, but those questions were in line with the main questions.

I opened the interview with a 1 minute description of my own understanding of TEL as an information infrastructure and to broaden the view to both social and technical aspect of my research. My idea was to encourage them to give both technical and societal storylines. The message was about my research purpose as well which is improving TEL R&D activity in direction of better life. I started with similar sentences:

“How to develop Infrastructure such as TEL, Technology Enhanced Learning? We are surrounded by infrastructures, we live, plan and work based on them and we are not aware of them until they fail. To enhance how we do, we need to be aware of them and difficulties we face to get connected to them. This is a study, all about awareness and to plan for better TEL projects.”

In coming three sections I will go through the interview notes and results. These three groups are selected from the theme of the questions which were designed for interview questions. First theme includes answers to those questions which were about how they joined reasons, interests and their collaboration and involvements. The second group are about the actual researches and projects, how they have been conducted and the methods and tools that are used. The third are the questions related to the issues, challenges and difficulties while doing the researches or doing development job. These groups of answers are definitely not given on exact question as per se. Since the interview was semi-structures interview; depending on the interest of the participant or because of the flow of the discussion answers did not follow the interview questions’ sequence.

4.1.1. Researcher and the Center, Motives and Collaborations

As R1 asserted, “research is not an individual process”. In first part I ask them how they joined the center, what their reasons were and how their collaboration and experience has been during their participations.
4.1.1.1. Who they are

I started the interviews with the introduction as I mentioned earlier. Mostly the first questions were about how the interviewee has joined the group, by any motivations or any story involved.

In most cases the bachelor, master and PhD projects and thesis were the start point of joining to the group. While for others, research interest specifically in computer science and TEL was the given reason. Also the language skills, teaching skills, having extra activity and influence of external research activities were mentioned as the reason of joining the group.

The participants have had participated in several projects with minimum of 2 or 3, and up to 10 projects or more.

There were different feelings toward the Technology Enhanced Learning (TEL) among the interviewees. While R5 and R6 had great interest in computer science and coding, even using the phrase of “Code Monkey”, R1 shared a great interest in TEL itself and with clear purpose toward the research. The R1 comments also is giving kind of definition for TEL research as mostly is accepted in the center:

R1: “IT should be used for a purpose and purpose should connect to human needs, Learning is one of the activities of human is learning, it happens in formal and informal settings, reading a book waiting for the metro or in the classroom in the lecture, therefore knowing the landscape of how human acts, the idea that technology that enhance that process both in formal and informal settings to serve that and to be innovative and creative and develop design and apply new tools and technologies, to enhance these human process…not limited for learning but supporting different kind of human process”

The research ideas are covering both formal and informal learning even though the projects are carried out in formal settings. IT is believed as a technology which is applied for learning as the domain.

There are clear motivations in the projects as we see in the R1 comment, it can be seen in other interviewees as well. R4 also believes it is covering informal and “formal learning” where it can happen outside the classroom “everyday phenomenon and then to connect back to the classroom”.

Interviewees had also great measure of personal interest and motivations, mentioned by R3 and R4. Teaching in university, having parents who are lecturers are given as pedagogical background. They were also interested the topic of TEL to use “advance technologies to support learning and teaching”. However it was mentioned that the PhD and master student’s interests could be irrupted by their thesis works since they are supposed to finish their studies.

4.1.1.2. Roles and Relationships

The members mentioned different kind of roles which they have experienced. Some of the interviewees have had an experience of promotion from being member of development team to more decision making roles. This has happened when they were advancing in the research skills, especially after joining as PhD candidates or higher research positions. They were expressing kind of a progress in their role over the years of being member of the center.
R1: “…Role shift after PhD, [to] principle investigator on the searching projects”

These roles are pure research tasks to more decision making roles, including participation in preparing research proposals, making decisions which determined the research directions, planning and organizing trials. These shifts are done either gradually by moving from master to PhD and graduation of PhD or appointment by leaders regarded as “organizational decision”.

The relationships in the center were not formal relationships and they sound to have a great deal of collaboration among the members. The relationships are regarded as “not very formal” and “easy to collaborate”. However it is structured in term of research organization as “formal collaboration” which has “more or less the same goals or something to aim towards”.

One of the roles that were discussed with interviewees was the role of writing the proposals and following the funding process by the interviewees. Few of them have had the experience of participating in proposal writing and it process. This brought role of third parties in the picture. By third party I mean the funding agencies and companies which are providing the funds. Writing proposal needed specific skills. They needed to convince funding agencies and companies in the proposals. The importance of funding and its tricky process was mentioned few times in the interviews. They have had to write in a way that people in charge in companies or funding agencies would understand even if they had no background in TEL. Also the content of proposal should motivate those stakeholders by presenting clear picture of the benefits and goals.

R1: “also there is a bit of the tricky because it requires a lot of efforts … writing a project application in 5 pages and convincing somebody to give you 1 million Kr, …. when you write you need to write so clear so even somebody that might not be familiar with the filed could clearly see the potentials and what could be results and what could be impacts for the society of your project application…you need to keep both research levels pretty high but also you need to be able to write those in a way that it make sense for non-knowledgeable or non-researcher”.

In addition there have been other organisational roles like “project leader” or “technical advisor”.

R7: “… someone it could be the project leader or one of the researchers…”

4.1.1.3. What they do

Experimental approach is most dominant in the narratives, R1 gave an example: “…failures as contribution like using wrong technology for specific setting, something does not work, Tomas Edison example 100 ways not to construct light bulb, How not to do things”.

Majority of the interviewees were describing the tasks as computer science research and development. They were using the word of “technology” when refereeing to their tasks. There have been other pedagogical or Human Computer Interaction (HCI) expertise have been among the members and taking part in the projects. However those activities were not referred in same priority and importance level by all the members. R2 perceived HCI and application research as “application” creating roles and not “computer science” research.
Generally among interviewees “E-learning” is seen as a “driving force” and a “domain” to validate the results against it. In this way interviewees see themselves in charge of technical research and not to make an application:

R3: “.., I just wanted to focus on the technology and how it works to exchange data then there were some people telling me that those tabs should not be tabs they should be buttons and these kinds of interaction and it's not the focus but those kind of people, of course they are involved in the project as well”

In particular R2 believed that TEL is a domain and the researches in software engineering should contribute to software engineering and not to its application.

R2: “..., you know if you talk about e-learning as a domain, you can build e-learning applications you can even test the applications and then you can do a PhD … but then you have to ask yourself the question what is the contribution, to the phenomenal understanding of engineering software systems …, so the domain should the driver for the research and should an it can validate the research but that's it…. we are building up knowledge where these kind of knowledge can be used for it might be useful to apply it elsewhere and see whether it would be ... as well, that we build some more long term knowledge”

This is despite R7, R6, R4 and R1 that believe that their research should contribute to the learning process. As mentioned in the research interests, some of the participants strongly believed that the research in TEL should benefit directly teachers, students and contribute to application as well as technical aspects.

4.1.2. Tools, Methods and More about the Research Work

The center have had quit experience in dealing hardware and software and that has been constantly updated in favor of new technologies, as R3 mentioned “everything [is] in BETA version”.

4.1.2.1. Hardware and Software

Various numbers of software, hardware and techniques were mentioned during the interviews. These technologies and methods were used for developing, communication and other research activities.

According to R1, R3, R5 and R6 the team has been using “multiple collaboration tools”, such as Skype, email, wikis and forums. For writing papers, they have been using Google Docs, Google Drive, DropBox and Mendeley. As hardware multiple servers were mentioned for saving code, sharing codes and projects, camera to communicate with overseas groups. Also NOKIA phones have been used in early days for experiments where they had the first capacity of having servers.

These tools are both in-house and also free available tools in the market. R1 and R3 explains that the center has “scheduling system for booking different equipments” and “own servers for wiki”. Also list of programming languages and developing platforms were given which were used and some abandoned in favor of new ones, such as Eclipse, ASP, HTML5, Android, Android Studio, C++, C# and Python and server side languages like OCL and Simbian.

The hardware and software have been updated several times since early days of first projects:
R1: “initially it was some small flash movies for the mobile phones primarily NOKIA Simbian platform years 2003/2006 after gradually shift to more advance staff, it was some Python development still for Simbian, one when we were introduced to Android and IOS devices when started a completely different approach of the development, right now what we are very much focusing is focusing on HTML5 which provides native capability to access to some of the native features of the phone like Camera/Geo-Location and so on”.

4.1.2.2. Methods and Principles

The center has certain methods and principles in conducting their researches. As the main research principles and methods iterative low fidelity prototyping, agile developments were asserted by R4, R1 and R3.

R4: “we have certain principles that they have to follow … one is called design if you develop technology for the end user the end user should be involved… we focus a lot of time in different design sessions and trying to understand what the users need….we work in a Agile methods…we try to work as close as possible with different stakeholders in this case teachers in the requirements we will elicit and we discuss with them many of this limitations will come already at the first stage before starting the design so we know which are scenarios we are developing for it”

R1 gives a definition of the work in center which is shared by others. The research is seen to develop a “robust system for data collection /data aggregation and visualization” having technologies like “mobile station for data collection/server-side engine for data aggregation/visualisation….on applying web or mobile and web technologies and tools for supporting learning processes”. As a result, most of the projects are about a) dissecting the technical problems into data collection and data aggregation and b) data visualization and aggregation on web and mobile summarizes. These technologies are supposed to support learning.

This perspective has resulted in certain generic solutions which center has been contributing in previous years. So for instance “generic tools for data collection [are] not dependent to how utilized in learning” and also it is separated from visualization tools. This means that solutions provided by:

R1: “detaching of learning scenario and dissecting it into smaller processes that could be targeted and provide us clear requirements how to utilize, Becoming more and more modular, module matches with processes, like data collection/data aggregation/data visualization and so on”

In term of direction of the researches, R2 mentioned not following certain standards in favor of having open hand in research. Some methods were used related to evaluation or literature review and not certain method in developing process where for example mathematical models are adopted. From R2’s point of view “interoperability” was not the concern of their research and this would be concern of the research if there is already “already existing system”. R2 also sees standards are required for solutions which “go to the market” and this does not apply for TEL research which they are conducting.

However it was discussed in several occasions with interviewees that the center in fact is dealing with interoperability issues, perhaps in different levels, with various locations, devices and scenarios. R2 also pointed out that there are outside tasks to be carried out in connection with indoor facilities.
R4: “interoperability and usability we are relying on XML technology everything we do so we can reuse and not only reuse but also to change, to transform content into context…. so the same data has multiple representations depending on the device and the settings this is quit crucial for us all this usability and interoperability… we have developed whole system it is called [Project Y] architecture which some of the software we have developed has been integrated with software in National Geographic”

The interoperability is even required and helps in the center’s own continuation. As the new PhD candidates join the team and build their projects upon the older projects, there is a need for certain interoperability so the continuity of the projects is guaranteed. It seems that “open source and open standard technologies” has been selected to meet this “extendibility/flexibility”.

There have been “different data collection requirements” and evaluation methods, such as user testing with list of tasks, user observation, screen recording, interviews and questionnaire. R1 mentioned “protocol developed by colleagues in Zurich” specifically for observation.

Project X and Y (section 4.1), which are most discussed in the interview, are focused on specific system to be designed and tested. However R5 reported that in the master thesis they have conducted also comparison research among two different technologies. This research has showed specific multi-touch technology is not welcomed by users despite being an option for collaborative environment.

4.1.3. Challenges and Issues

Several dimensions of challenges and issues in different levels of development and research activities were brought up during the interviews. These are reported from incidents in the projects and from direct observation of researchers.

4.1.3.1. Users, Developers and other Groups

As R4 stressed various stakeholders in software development as a whole ecosystem creates numerous issues in TEL R&D.

Apparently the project faces problems at even first stages where the center has to convince fundraising agents. R1, R3 and R4 mentioned quite challenging proposal writing phase where they have to come up with both scientifically strong and also easy to understand proposal to convince fund raising agencies that may not be familiar with the TEL. In addition these funds are not enough to support the users after delivering the application. So the sustainability of the projects becomes an issue.

Another issue was the conflicts among stakeholders, computer science developers and other fields like HCI. R3 mentioned that they wanted to focus on the “technology” and their concern was not to identify graphical interactions like buttons or tabs which were suggested by HCI researchers.

A point was brought by R3 about the problem that they faced in collaboration with new team members. The new members would leave for some reason or may not be able to understand and do the tasks properly. So lots of time and effort was wasted to train or explaining the projects and tasks for them.
R2 sees the culture of different groups as a challenge. Perhaps not in the center itself but when it comes to research and supervisory of other research groups. Also R2 mentioned that working with companies would be different:

R2: “if you work with people with company for example these people they are taking a holiday in the summer, they are not as responsive and so on then you have to accept that sometimes you have to treat people sometimes you have to adopt a bit”

Other issues were related to the requirement gathering and users. Users, such as teachers have requirements while developers may not follow those wish lists, R3 stressed that:

“We are doing quite a lot project that is based on our perspective and we are focused on a lot computer science and technology …., may be they have some needs that we take for granted”.

R6 also mentioned that developer may modify the requirements because of feasibility of the projects.

However participants believe that these requirements are subject to scrutiny. It was mentioned that sometimes it is very exciting for teachers and students to try new technologies with universities. So when students and teachers were interviewed about how nice is their experience, the answer would be “yes” because of the excitement of using new technology or collaboration with university. Also R5 brought up that teachers and students did not feel comfortable to participate while they were in university, doing testing or other activities related to the projects. R7 was concerned about the time and energy that teachers and student are putting into these projects and even using their free time, they are not gaining much.

R3 concludes that “I would say that 90 percent of our requirements are in-house requirements not that the clients are actually asking us”.

4.1.3.2. Software, Hardware and the Process

Robustness and sustainability of the developed systems is the most referred concern in the interviews. R3 and R2 have focused on this issue in PhD project more from technical perspective. Also R4 mentioned the sustainability of the project itself where more budget is needed to cover the project but funding agencies do not support long term and sustainability in full. Overall robustness and sustainability, indifferent levels, is seen as a serious issue in learning scenarios.

R3: “… like Internet, interruption by users that have slow internet …whenever he sees the video for example it’s quite delayed, then he posts a question to the rest of the group, that just as a scenario, ok, and then everybody gets like so what are you meaning with that because it's out of context it's something that let's say one minute ago, what do you mean with that, and he managed to interrupt all the class”

R7 reported that during one of the researches they needed to perform extra observation which they were not ready for it. They did not have proper forms or guidelines. Also R7 mentioned an issue of such a sudden change where they had to record the interview and there was no proper tool. So they have conducted the interview using camera as voice recorder (with closed lens so the identity of interviewees are not revealed) and for some reason those records are lost.

R1 reflected the issue of requirement change in another words. While they have been conducting a project, they have found out that the technology that they have chosen was
not the best choice and they were forced to change it. It has taken a year to complete requirement gathering for the new technology.

R2 believes that there is issue with combining the two aspect of technical and use of e-learning research. The conflict is to balance between the rigorous of engineering practice and the domain which requires pedagogical elements and application. While the research, should contribute to the computer science research, R2 believes that domain and the application of technology is dominating. This approach believes that robustness, for instance, is a common issue which needs to be dealt with and is not domain specific.

R4 added the issue of content, reusability of software and representation of data in multiple devices.

R1 mentioned the dependency on third parties for other technologies like sensors in both quality of technology and accessibility of the instruments. For example water quality was tested in one of the projects by students and this was provided by only one company which they had to rely on them. Also if these instruments are going to be used by school there is logistic and cost issue, i.e. not every school can afford them and if they need to borrow there is a logistic issue. Perhaps also it may political decisions to invest on these instruments for schools which it is again another problem.

R6 had great experience in dealing with standards and policy providing organizations. In fact R6 believed that these standards are too complex to be followed by teachers as content providers. R4 also agreed with the fact that teachers are the best for providing the content and it was mentioned that the whole industry is accepting it.

Finally there are issues which are suggestive in a way. Participants see certain issues with process of research where it could be improved.

The scalability issue in the evaluation of developed systems was mentioned by R1 and R3, scalability in number of users and period of tests. Basically they meant that testing 10 users is completely different from real case scenarios with thousands of users. Also test which would run for few days may not be reliable for systems where it may be used for years. The evaluation and assessment problem was brought up few times in interviews which make it difficult for the center to measure its success whether they meet the targets or not.
5. Analyses

The purpose of this section is to analyses the findings based on the theories. This will help to answer the research questions. The order of sections 5.1, 5.2, 5.3 follows the order of research questions.

5.1. Analytics of SCOT

In this section I will use SCOT concepts (i.e. relevant social groups, interpretive flexibility and stabilization) to reach to some understanding of the narratives and to start making sense of what has been gathered during the data collection.

5.1.1. Relevant Social Group

I can say that the interview with target group, the TEL researchers, was very fruitful in sense of knowing the R&D environment. The center has fairly good 10 years of experience in TEL R&D field and is connected with various stakeholders, pedagogical policy makers, TEL R&D institutions, pedagogical institutions and etc. (section 4.1). This provided valid insight into the “relevant social groups” which were supposed to be identified.

Beside “Computer Science” experts, as more direct coding and developing skills involved, other related CS expertise such as HCI researchers also played role with different perspectives (section 4.2.1.3). In between I shall separate students which participated in the research activities from the senior researchers. This could be justified by the fact that their thesis was their main concerns and obviously this affects their contribution and concerns with the projects (section 4.2.1.1).

Furthermore mainly so called “clients”, also were referred as “student and teachers”, are the social group with limited effect on the research (section 4.2.1.3). However those limits are not in the scope of my thesis. Other important social group is the funding agencies which they have their own interests and impacts on the decisions (section 4.2.1.2). These funding agents and their partners who perform the review of the proposals may not be in the same field of TEL. So this would vary time to time upon different projects. In addition the organizations which are involved in the standard settings seem to be another relevant social group but their influence remains unclear. As explained earlier, these standards seem to be too complicated to be followed. I was not able to trace any use of those standards during the development activities. Only one interviewee was doing some research on those standards.

These social relevant groups are summarized in figure 6. The analysis is based on direct reference of interviewees and also using the conflict reports by them.

There are conflicts of interests among the groups such as the CS and HCI researchers. This is due to the fact that every domain may look for its own interests and research questions. Also obviously the “clients” (i.e. teachers and students) have different interests which were compromised upon the actual development process. Referring to the requirements several times as “not actually a requirement” or “wage requirement” shows that the developing team is not getting fully the perception of students and teachers. But of course that would require another research itself to provide proper evidence to find out the students interpretations and expectations of the technology in learning environment. The ever changing technologies were given as one of the reasons for not having clear requirements. But also there was a feeling that research group could
do better in that sense and make better relationships with users. So the link of the feedbacks into the TEL R&D center is not broken in social interaction.

![Figure 6 TEL Relevant Social Groups](image)

Having these social groups, figure 6, does not mean that they are affecting the R&D activities with no interruption. This means that there are barriers that these groups are not able to influence the R&D activities within their own limits. For example, having mostly master and PhD students, besides the being very useful in having active and young environment, has some consequences. The PhD students mentioned distancing from the center activities when they had to concentrate on their thesis. Perhaps this could cause some damage to the research activities since the thesis has the priority. However for participants like R3, sometimes personal interests are stronger than being worry about the finishing PhD itself. So they would continue with the projects despite any delay in the thesis.

### 5.1.2. Interpretive Flexibility

The interpretations which are discussed in this section are only from the center members. This means other social groups which are identified in previous section require separate research to report their ideas and interpretations about TEL projects.

The majority of the projects in the group have covered outdoor activity. As mentioned in the interviews “making learning exciting”, “connecting the indoor and outdoor activities” and “technological intervention” are the motives and the way TEL R&D activities are perceived. So in that sense for the research team:

1. ICT should be present in the learning environment
2. ICT is supposed to create connectivity in different levels, place and time
3. ICT intervention is a necessary

The group members see their task to make available the most “sustainable” technology for learners. Technical failures are perceived a negative side in most cases, even though one interviewee gave an example of learning from the failure of devices. So there is a strong feeling toward creating a “real working technology”. The fear of feeding
inaccurate information, losing the attention of students and wasting the teaching and teachers’ time seem to be valid reasons to avoid any technical failures.

There is a conflict in the way the TEL is pictured by the center’s members. TEL for some of them is about software engineering research and for some use of technology is as important as the development.

For some of the researchers, users who are less ICT educated, not aware of technical advances and the most recent options. The team sees the developers’ task to provide options. The team does not feel this gap as positive and constructive fact. But it is generally accepted.

The academic prestige and cooperation with university seems to play a role in the stream of requirements, i.e. collaboration with university itself is welcomed by schools, teachers and students regardless of the results and this cooperation and also trying new technologies is satisfying. University is perceived the knowledge body who resides the advanced knowledge.

5.1.3. Stabilization

As mentioned earlier, because of the need for more stable systems, it seems the modular design is more favored whereby the system is seen in parts which can be addressed and researched so a more robust system to be developed. This is supported by the computer scientist’s approaches in favor of robust systems, as we saw in comments by the members like R2 and R3.

Based on the interviews, the market is dominated by the open source base technology, such as Android and HTML5 that seem to be the current and future trend. The open source solutions are accepted solution by the team as explained earlier.

Finally interoperability leads to use of XML base systems and applications which are sought to have flexibility in use by various other systems, contents and applications.

Other than these I was not able to identify any certain stabilization. The center has an experimental environment. Despite close relationship with companies to provide funds, the center is not market oriented in a sense that it is not targeting to sell any of its products. For this reason stabilization of solutions is not likely to happen. The center works as a laboratory, based on differentiation Bowker (1994) makes to present the evolution of its case company.

5.2. Use Issues and Concerns of the TEL R&D

Infrastructural perspective of TEL allows us to analyze the R&D activities and to see potential issues in later use stage. As explained earlier Star & Ruhleder’s (1996) help to list issues of users of an infrastructure.

Earlier the narratives and analysis showed that the developers are concerned about the operability, system failure and adoptability of the system according to the context of use. Most of R&D efforts are focused in issues which are related to the installations and use of parts and elements. As Star & Ruhleder (1996) explain these are considered as first level issues. Most of the research topic are focused on the test of certain technology. The question is mostly about whether this technology is working or not and is about an inquest on users’ exposure to that technology.

The center also researches the context of the use in indoor and outdoor which are considered as second level of issues based on referred classification. The researchers
are interested in creating “robust” and “stable” technology which is able to work in various contexts. This allows the users to be able to adapt to the context which education is conducted.

In addition from the participants’ perspective usability is equivalent to interoperability. However reducing the usability of an infrastructure to interoperability among systems and developers risks the ignorance of the other levels of use issues. Addressing interoperability helps to resolve multi-device, multi-application and multi-content management. However we see little efforts in addressing third level issues where users would be given alternatives in term of functionalities or devices.

In one example, R1 mentioned that the observation showed that students use their own phones as calculator despite researchers’ expectation. This seems natural for the students that the phone’s calculator can be used as part of their learning process. Also based on the interviewees’ comments, there are non-stop interventions of ICT in learning environments, either for learning purpose or not. Nevertheless the R&D activities are focusing on single, isolated and separately tested solution. This can result in a the systems which are isolated and underused when it is put together with many other ICT devices, systems and applications. Also these isolated researches have not included the presence of non-IT educational instruments such as whiteboard. Overall there is no consideration of the concurrent uses ICT nor non-IT tools and systems.

Furthermore it was brought up that the projects are testing certain technology in limited time and with limited users. This creates potential usability issue in real case scenarios where users may abandon a system or application in favor of other solutions which are available in long run.

### 5.3. Framework for TEL Development

There are many characteristics TEL development that were mentioned by participants and are affecting the design of TEL systems and applications. In this section I will compare the characteristic of TEL development with Zimmerman’s framework (2007).

The center is an experimental R&D group. While the center is dealing with testing new technologies, at the same time it needs to address several use and application issues to keep the relevancy to the TEL domain. Mostly low fidelity prototypes from single system and application are developed in order to test the projects. In this sense the center is neither considered as pure research center nor offers fully developed TEL projects. In case of maturity, this center remains in middle level of between pure research and a developed infrastructure.

The various stakeholders, software and hardware represent the complexity of TEL R&D activities. All the reported conflicts, challenges with software industry are indication of a complex system which requires negotiation and collaboration of all parties in its design and development. So we are able to add complexity as another characteristic of TEL development.

There have been reports of other tools such as water quality testing tools which are not designed by TEL developers. This also can another dimension of the framework.

The influence of other stakeholders such as budgeting agents affects the center. Also there are organizations that play role in setting the standards, educational system or political decisions regarding school budgets and management. Figure 7 summarizes the framework elements.
In this thesis the framework is the result of the data collected from R&D researchers and developers. I did not have data from their users. So in comparison with the original framework of Zimmerman (2007) the characteristics of users is not added to the framework. To add this part of the framework, it required to have the perceived viewpoint of users as Zimmerman has conducted so the users’ capability, expectations and perceived needs would be investigated. Also some observation of the system use would be required to identify the characteristics of users. In addition since most of the projects which were discussed with participants are not installed and again there is no direct feedback at least in the scope of my thesis, hence I was not able to discuss “mechanism of coordination and feedback” as is in Zimmerman’s framework.
6. Discussion

In this part I will discuss two topics in my thesis, using the analysis. Firstly, it is the TEL as an infrastructures. Secondly, I will discuss the stakeholders which were identified during the interviews.

6.1. TEL as an Infrastructure

The systems and application which are developed in the R&D center are the future technologies which will be used in learning processes. This covers classrooms as formal studying environment and informal environments like beside the lake as we take a walk around the lake. Literally they are going to be part of our modern life as discussed earlier (section 2.3.2). This can be extended by the dimensions which were identified earlier.

Interoperability as one of the factors is an important strategy toward an infrastructural development. It can be an advantage when talking about the wider scene of an infrastructure where other parts and elements are able to connect and work with it. This brings the openness in Hanseth’s definition of infrastructure (Hanseth, 2000). The stakeholders that were identified from users to various developers and researchers, organizations where manage the funds or standards, shape the heterogeneous dimension that was Hanseth describes. Furthermore the whole R&D activities present the deep relationship with existing infrastructures such as education system (i.e. the relationship between university and the schools), funding roles and regulations, software industry (i.e. open source capabilities compare to other sort of platforms and programming languages) and the fast changing market has pushed the team to use certain technologies, open source technologies and standards, and leave others. So TEL is an installed base like other infrastructures.

Nevertheless the thesis is not able to identify the feedbacks, because the center is in experimental stage and had few if any installed system. There are limited feedbacks during the projects which I find it problematic. This is affected by the existing authority of the university as body of knowledge as an existing system. As mentioned in the interviews, students are excited to use new technologies and collaborating with the university. I believe it is problematic because it is taken for granted that users’ involvement is good enough in design process and other factors are not acknowledged. This perhaps presents the installed base dimension where TEL researches are facing other existing setups like the concepts of university as the body of knowledge and the education system.

Similarly the analysis would provide evidence to compare with dimensions which we learn from Star & Ruhleder’s (1996). Firstly the center members mostly believe that their research is highly dependent on users. Use of TEL systems and applications are the concerns of center so that these technologies become an infrastructure (ibid). I believe this awareness is a positive fact that allows further improvements. Using camera as voice recorder, little tricks to get the proper funds, sudden change in data collection are all articulated works in TEL R&D activities. This task has to balance between technical aspects and the researches in TEL as the domain.
6.2. Variety of Stakeholders

Through the collected data and analysis, I was able to find number of the stakeholders who are contributing to TEL R&D. Additional to the relevant social group (section 5.1.1) I identified long-term policies for formal education and the ICT market trends. Every stakeholder plays its role in this puzzle.

Governments, or the national body of governance, seem to have two major roles. One is their presence in the funding market and the second is the educational policies. Both roles appear to be crucial. In one hand the government helps to fund and plan great TEL R&D projects. I have discussed the funding role in the related social group section. They would influence TEL R&D direction as we have seen from the interviews. The funding body’s concerns and expectations, by experience, are followed in planning stages of the R&D projects. In another hand government can facilitate implementation of TEL systems through the educational policies. Interviewees mentioned the importance of school policies in availability of tools. This makes it possible to achieve a nationwide installation of brand-new TEL systems and applications and their related technologies for education.

Based on the interviews the ICT market apparently has affected the whole R&D cycle. The success story of Android in mobile market has determined the systems and application which are used for R&D purposes. Also Android made the mobile available for many because of its price compatibility. This has accelerated the whole R&D cycle. So, as I presented in Zimmerman’s framework (section 5.3) ICT market is a major element for TEL cyberinfrastructure R&D and this is very possible to have crucial changes in TEL R&D because of success of certain products in ICT market.

However having various stakeholders, we surely witness number of conflict of interests among them. The clear conflict from empirical data apparently the research rigors and relevancy sound very differently to two groups of the researches. Some look at the TEL as the heart of the research while some as computer science professionals only consider the pure computer science as the technology and as the end result of the research. It means the later use of the technology is no concern of the second group. Even the first groups, who believe in TEL more than others, are annoyed with HCI researches comment on the design of the page which interacts with students and teachers. In my understanding, this is a natural scientific dispute. But this creates dilemma if all these groups are supposed to work together to develop a system while their perceived end results are not matching. The issue gets bigger, as reported by interviewees, when the project is facing time and money limits.

Even though the researchers are able to come up with solution for those issues, the next challenge is to meet the user’s expectations. So the question is, are they obligated to do so?

The interviewees were split in the response. Some believed this is the duty of the researchers to fulfill because of public funding and the users’ allocated volunteer time, while others were very serious about their responsibility to the science and rigor of their researches. Perhaps the issue arises when we are addressing multi-discipline fields with researchers who see themselves dedicated to certain fields. The computer science researchers would not see the importance of use issues while HCI researcher would not be able to realize that how crucial it is to have the wireless connection working before giving thought to the colors of the button to click.
For this reason, I could think of researchers who are TEL researchers, who have both interests in technology and also in use. The multidisciplinary courses and researches would help to this problem in future.

6.3. Reflection on the Applied Theories

The fact that the SCOT concepts have huge advantages in understanding social context of the technical development helped a great insight to this thesis. Also Star and Bowker’s researches and other similar understanding of Infrastructural developments provided me with proper tools to look into this complex TEL development.

However I found these great concepts are lacking major “How To” in sense of finding related empirical. While everything looks related it is not clear how evaluate and measure their importance. This methods and theories are great in drawing a big picture of the problem and identifying major players, existing systems and technologies, social groups which have eventually lead the TEL development in certain path. Meanwhile it is very difficult to provide final key practical solutions.

This practicality issue could be one of the reasons that despite good explanation of the issues and situations by SCOT and STS, I found it difficult to conclude on practical advices and I suggest further future research in several other social related groups and wider development samples which even those may give a very complex picture with few practical outcomes.

Despite this finding and personal experience in this research I can see a great advantage in having these kind of researches to cover very much shortcoming of other narrow insights. Perhaps more theoretical work is required in STS to provide more accurate and practical theoretical tools (Jirotka, Lee and Olson, 2013).
7. Conclusion

This thesis aimed to explore the Technology Enhanced Learning (TEL) research and development (R&D) through investigating the parties involved, the current challenges and the issues addressed by those R&D developments and finally the TEL R&D characteristics as an infrastructural development. To meet these aims, I tried to answer the research questions.

The social aspect of the technology has been the concern of IS literature in past few decades. Social Construction of Technology (SCOT), one of the early theories in science and technology studies, sees the technology as a result of a social process. The interaction among number of the social groups and their interpretations of existing problem results in new solutions and technologies. So technology is relying on interpretations of social groups and previous solutions and technologies. Infrastructures such water pipelines, are an example of technology built through social process upon historical background. Technology Enhanced Learning (TEL) research and development perhaps is an emerging future Infrastructure. It would be useful to investigate its social process and its interrelated backbones which results in TEL products in order to identify its shortcomings.

RQ 1. What could be the related groups, the activities and the perceptions in the TEL research and development?

To answer the first question, from SCOT point of view, in which the technology is believed to be socially constructed, this study was able to identify relevant social groups, number of the interpretations among those social groups and few closures as a result of these social interactions. The relevant social groups were identified, applying qualitative methodology. Interviews were conducted with 7 researchers from TEL R&D center. I was able to identify 5 relevant social groups, i.e. computer science researchers, funding agencies, HCI researchers, PhD/Master/Bachelor students and students and teachers as clients. During the interviews I found that not all group members are engaged in TEL research and development and few of the group members who had been involved were not available in the period of interviews.

These 5 relevant social groups are investigated from the interview sessions. Interviewees were speaking about their actual experiences in the field with either one of these social groups.

The ideas and approaches which were reported in the interviews are noted as the teams’ interpretations. The R&D team believes ICT presence and intervention is necessary in learning environments. In term of TEL development, they aim for more connectivity in different levels, places and times. Sustainability in different dimensions such as in usage and development cycle is very important, which is referred as “real working technology” with minimum technical failure with highest availability.

However there are conflicting views whom should R&D activities contribute. Some believed that they only should contribute to the technology and software engineering body of knowledge while some thought that the TEL users are important as much as the technology.

The R&D team is assumed to provide and explore options for users (e.g. teachers and students) who are less ICT educated. In fact number of interviewees do not see it the
best way of dealing with the requirements. Some of the team members think that
providing option by researchers does not fulfil the requirements.

University’s academic position also plays role in how R&D is performed. Schools,
teachers and students like to collaborate with universities as a prestige and superiority.
It was reported that students and teachers would behave differently while attending the
sessions in university, resulting in asking less questions and being more silence during
the sessions. Also teachers and students are so excited to try new technologies through
participating into the projects.

This study finds little stabilization and closure. These stabilizations are in form of the
modular design, robust solutions, market dominated products (e.g. Android operating
system, HTML5), and XML based designs to achieve interoperability and flexibility
toward different systems and contents.

RQ 2. Which issues are addressed by TEL R&D development?

For the second research question, TEL systems were perceived as an Information
Infrastructure and the related research and development as an Infrastructural
development. Previously I discussed the openness, heterogeneous and installed based
concepts using the findings. The thesis investigated the issues which are addressed by
the R&D center from infrastructural development point of view. To answer the second
question, I have asked the interviewees to explain their projects, project goals and
achievements.

The findings shows that the developers are concerned about the operability, system failure
and adoptability of the system according to the context of use, i.e. variety place and time.

They address the two groups of issues based on Star and Ruhleder infrastructural
development classifications, mainly the technical installation issues and contextual use
issues.

However the thesis finds no evidence that the third group of use issues are addressed
properly in the centers’ R&D projects and activities. The third group of the issues refers to
the alternative systems such as the use of blackboard in the classroom beside the TEL
applications and systems. This could result in abandoning the TEL systems in favor of other
tools or applications. This study suggests that not addressing alternative/parallel existing
tools/equipment/application/systems in educational environment in the TEL R&D could be
one of the reasons that TEL applications and systems are under-exploited.

RQ 3. What are the characteristics of TEL research and development as an
infrastructural development?

Finally for the third question, using existing Zimmerman’s framework of
cyberinfrastructure development, number of the characteristics of TEL R&D were
listed:

1) Maturity of R&D activities
2) Complexity of TEL systems
3) Existing third party hardware and software
4) Influence of other roles in the TEL R&D

These are characteristics which this study was able to list based on developers’ point of
view. I have asked questions related to their type of activities and overall TEL R&D.
Part of the Zimmerman’s framework remains unstudied due to the fact that data collection was limited to researchers and developers.

As the result of this study, I could conclude that TEL R&D is complex and it is in its early stages of maturity. There are many players in the field and many tools which influence the research and development of the TEL systems. This elaborates the importance of third group issues (according to Star and Ruhleder classification) where existence of various systems is foreseen. Unfortunately this study finds that the third group of issues is not addressed by R&D projects and activities.

TEL R&D is a complex task. In one hand it is highly relies on various existing rules, regulation and systems upon its development. In another hand there are many players and tools which influence its use environment for learning purposes.

This study attempted the use of infrastructural development approach for TEL R&D as comprehensive theoretical base. TEL as an Information Infrastructure, becomes an infrastructure for learner upon its use beside variety of others tools and systems in different environments, places and time.

7.1. Reflections

I believe Infrastructural development approach shows a great capacity to provide proper approach to understand TEL R&D, address its challenges, to present the complexity and to provide a framework for it to build.

However Infrastructural studies are still in their early stages and are very rare. Especially for ICT projects, there are few areas which are categorized as infrastructural studies. To identify more research areas, much more researches are needed so we can look for more theories and frameworks. Cyberinfrastructure is currently the forefront of these researches perhaps because of ambitious in academic environments. But of course we would be able to identify more examples like TEL systems and applications to enrich the theories and researches.

Using the theories which I have brought into the thesis helped to trace the roots of infrastructural studies. SCOT gives the proper historical background to understand the socio-technical nature of infrastructures. SCOT researches, I believe, are pre-requests to grasp the essence of this approach. Since this a new approach for ICT I found it very useful to return to the roots of these theories to have better understanding of values and their purposes.

After the interviews, I did realize the importance of including more parties in the interviews to have the broad picture required in the theories, like the parts I was not able to cover in Zimmerman’s framework. This of course needs more resources in time and man-power to cover. However I believe the thesis was successful in illustrating the certain aspects of TEL like its complexity and interrelationships.

7.2. Future Research

The thesis is conducted with all limitations in the resource and knowledge of the author which can be improved with wider collection of data and more detailed analysis. However I believe one of the future work could be the extending the research into users, teachers and students, and other social group which were identified in this thesis. Definitely there are certain perceptions which are coming from other stakeholders. This may provide more complete picture in the future.
Bibliography


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Appendix 1: Interview Questions

The interview questions were emailed to the participants in the format below:
1. How did you joined to the projects or researches related to *** center?
2. How was/has been your participation and collaboration in the projects?
3. How the learning was/is defined while working on the project? (your own experience)
4. What were the software and hardware used to conduct the research? (Personal/Among Members /Other research sources)
5. Would you please explain any standards or methods that you have used during the project? (Personal/Among members/Other research sources)
6. How was your relation with initiative decision making processes like ideas or funding?
7. Please describe the challenges and the possible solutions applied during your participation.
8. Have you been involved in any other TEL projects? Please describe.
9. In your opinion, what have been the contributions or use of the projects?
10. Would you like to add anything which has not been covered?

*** is the name of the center

Beginning of the interview sessions the questions were printed as shown in figure 3. and given to the participants to help them on the questions.

<table>
<thead>
<tr>
<th>Question</th>
<th>Critical Points</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How did you joined to the projects or researches related to *** center?</td>
<td>Joining</td>
</tr>
<tr>
<td>2</td>
<td>How was/has been your participation and collaboration in the projects?</td>
<td>Project goals – Research experience – exact research areas</td>
</tr>
<tr>
<td>3</td>
<td>How the learning was/is defined while working on the project? (your own experience)</td>
<td>Learning definitions and how it has been defined (process of creation and decision making)</td>
</tr>
<tr>
<td>4</td>
<td>What were the software and hardware used to conduct the research? Personal/Among Members /Other research sources</td>
<td>Software – Hardware – space and materials used during the research</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Method/Classification</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5</td>
<td>Would you please explain any standards or methods that you have used during the project? Personal/Among members/Other research sources</td>
<td>Classifications – Standards - Methods</td>
</tr>
<tr>
<td>6</td>
<td>How was your relation with initiative decision making processes like ideas or funding?</td>
<td>The relations and networks of ideas/funds to other projects/organizations</td>
</tr>
<tr>
<td>7</td>
<td>Please describe the challenges and the possible solutions applied during your participation.</td>
<td>Important challenges – Classification of challenges</td>
</tr>
<tr>
<td>8</td>
<td>Have you been involved in any other TEL projects? Please describe</td>
<td>Networks and their relationship</td>
</tr>
<tr>
<td>9</td>
<td>In your opinion, what have been the contributions or use of the projects?</td>
<td>Specific results contribution and use of the projects</td>
</tr>
<tr>
<td>10</td>
<td>Would you like to add anything which has not been covered?</td>
<td>Open to the interviewees opinion</td>
</tr>
</tbody>
</table>
Appendix 2: Consent Form

About the project

*Thesis Topic (The possibility of changing the title is not waived)*

Infrastructural Issues in Technology Enhanced Learning Development

A short Summary

This study intends to identify and discuss the issues upon the development of Technology Enhanced Learning (TEL) systems as long term projects and as infrastructural developments.

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About participation in the project

Data Collection Methods for this study

The main form of data collection is the use of semi-structured interviews. The questions in the interviews aim to elicit the interviewees’ experience of his/her involvement in (Name of Center)* center projects which shed light on the developing related issues in Technology Enhanced Learning (TEL) projects.

The participation in the interviews is voluntary-based. Interviews are going to be done face to face and only one participant at a time. Place and time of the interviews will be decided by the participants wherever and whenever they feel the most comfortable. Interviews last between 30 to 60 minutes. Interviews are going to be recorded by the use of voice recorder with the permission of the participants.

Participation Rules

1. The participants are 18 years old or more.
2. English is the main language of the interview.
3. Participation in this study is voluntary-based.
4. Participants in the research can only access to their own data at any time.
5. Participants in the research can leave the study at any time and also can ask for removing their provided data at any time without the need to provide any explication.

6. Collected data from participants will be used for master’s thesis project and, if possible, a research paper.

7. Data is going to be recorded by using a voice recorder with the participant’s permission. If participants refuse the use of voice recorder, note-taking is used instead.

8. Supervisor and the researcher are the sole persons who will have access to the recorded data.

9. All the data provided by the participants is going to be deleted after the publication of the master’s thesis and, if possible, a research paper.

Scope and Limitations of this study

This project will be conducted in Växjö. The participants are 18 years old or more, selected because of their involvements in (Name of Center)* center projects. This study to elicit the interviewees' experience of his/her involvement in (Name of Center)* center projects which shed light on the developing related issues in Technology Enhanced Learning (TEL) projects. Therefore, the research is limited to the topic and the centers’ publications and scholars.

Ethical Issues of this study

1. The personal information and answers of the participants are kept confidential.

2. Gathered and analyzed data are only accessible to supervisor and the student who carry out the research.

3. Participants remain anonymous by the use of pseudonyms instead of their real names upon their request.

4. Participants are not photographed or filmed.

5. Participants are informed that they may be contacted for a second time so that they can check the validity of the transcribed interviews.

6. These questions will be used for research purposes only.

Consent

I agree with audio recording of data. Yes □ No □ Conditional □

Please indicate:

________________________________________________________________

I understand the above explanations and agree with the statements above. Yes □ No □

Any further condition(s) or explanation(s) from participant:

_____________________________
I understand that my participation in this research is voluntary-based and I can withdraw from the research anytime I want without the need to provide any explanation. Yes □ No □

I understand that I can ask researcher to remove my data any time I want. Yes □ No □

By signing this document, I consent to participate in this study and the data/information that I share with you can be used in your master thesis “Infrastructural Issues in Technology Enhanced Learning Development” and, if possible, a research paper.

Signature of participant

Date

Place

(Name of Center)*: The name of the center is not enclosed throughout this thesis.