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International Interaction Forms in Global Collaboration Networks between the Information Technology Industry and Engineering Education

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ACADEMIC DISSERTATION
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the Board of the School of Management of the University of Tampere,
for public discussion in the University Chapel,
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Contents

List of Tables

List of Figures

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My experience of collaboration between the IT industry and higher education dates back to the beginning of the1990s when I was working in the IT industry holding various positions. From 2001 I have been working for higher education, and collaboration with the IT industry has all the time been important in my daily operations including also international collaboration. This background made me interested in studying international collaboration and related interactions and further to select this topic for my doctoral dissertation.

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Abstract

This study was carried out to find and explore current forms of international interactions in collaboration networks between the global information technology industry and engineering education. Forms of interactions between industry and higher education were first studied through a literature review of previous studies on country-specific interaction forms, because almost all published studies on interaction forms in collaboration between industry and higher education concerned country-specific forms of interactions. The findings of the studies were used as secondary data in this study for comparison. There were only few previous studies available on international interactions between industry and higher education and none of them examined different forms of interactions. Thus there was a clear gap in research which this study for its part aimed to fill.

Empirically the topic was examined as a case study where global IT companies with their global collaboration programs formed the cases. The primary data for the study was gathered from the documents of the collaboration programs of global IT companies operating in Finland. Also interview data was gathered as additional primary data. The respondents included both IT industry respondents and higher education respondents. The secondary and primary data were analyzed by thematic analysis. The findings of the primary data analyses indicated that the main forms of international interactions were knowledge transfer, human resources recruitment and funding acquisition. The results of the program data analysis were in line with the results of the interview data analysis. Furthermore, the results of the primary data analyses were compared with the results of the secondary data analysis. As a result, the international interaction forms found in this study seemed to support fairly well the found country-specific interaction forms. The main difference was that the different types of interaction forms on the international level, especially in knowledge transfer, were considerably fewer than on the country-specific level. The knowledge provided by this study concerning international forms of interactions could be used for development of collaboration between industry and higher education. Similarly the knowledge concerning country-specific forms of interactions summarized in this study could be used for development of collaboration on the country-specific level.

Furthermore, a theoretical description of bidirectional information flows in collaboration networks was proposed in this study. Understanding the function of a collaboration network requires understanding the ways information flows in such a network. The description was developed by applying the voltage and current laws from electronics engineering, using the circuit analysis method to model information flows. The description takes into account the heterogeneity of the collaborating parties in their knowledge of the collaboration fields and the formed information flows. The proposed theoretical description could be used for example as a tool in the development of collaboration between industry and higher education.

Keywords:
forms of international interactions, information flow, collaboration network, network, collaboration, engineering education, higher education, IT industry

Tiivistelmä

Tämä tutkimus tehtiin globaalin tietotekniikkateollisuuden ja insinöörikoulutuksen välisten tämänhetkisten kansainvälisten yhteistyömuotojen tutkimiseksi. Yhteistyömuotoja teollisuuden ja korkeakoulujen välillä tutkittiin ensiksi kirjallisuuskatsauksella sisältäen aikaisempia tutkimuksia kansallisen tason yhteistyömuodoista, koska lähes kaikki julkaistut tutkimukset teollisuuden ja korkeakoulujen välisistä yhteistyömuodoista käsittelivät kansallisilla tasoilla käytettyjä yhteistyömuotoja. Tutkimusten tuloksia käytettiin tässä tutkimuksessa sekundääriaineistona vertailutarkoituksessa. Aikaisempia tutkimuksia kansainvälisestä yhteistyöstä teollisuuden ja korkeakoulujen välillä löytyi vain muutamia ja niissäkään ei ollut tutkittu erilaisia yhteistyömuotoja. Näin ollen aikaisemmassa tutkimuksessa oli havaittavissa aukko, jota tämä tutkimus osaltaan pyrki täyttämään.

Empiirisesti aihetta tutkittiin tapaustutkimuksena, jossa globaalin tietotekniikkateollisuuden yritykset globaaleine yhteistyöohjelmineen muodostivat tutkitut tapaukset. Tutkimuksen primääriaineisto kerättiin Suomessa toimivien globaalien tietotekniikkayritysten yhteistyöohjelmien dokumenteista. Myös haastatteluaineistoa kerättiin täydentäväksi primääriaineistoksi. Vastaajat olivat tietotekniikkateollisuudesta ja korkeakouluista. Sekundääri- ja primääriaineistot analysoitiin käyttämällä teema-analyysiä. Primääriaineistoanalyysien tulokset osoittivat, että pääasialliset kansainvälisen yhteistyön muodot olivat tiedonsiirto, henkilöstöasiat ja rahoituksen hankkiminen. Haastatteluaineistoanalyysin tulokset tukivat hyvin tapaustutkimuksen havaintoja. Lisäksi primääriaineistoanalyysien tuloksia verrattiin sekundääriaineistoanalyysin tuloksiin. Vertailu osoitti, että tutkimuksessa löydetyt kansainväliset yhteistyömuodot näyttivät korreloivan melko hyvin havaittujen kansallisen tason yhteistyömuotojen kanssa. Pääasiallinen ero oli, että kansainvälisellä tasolla käytettiin huomattavasti vähemmän erilaisia yhteistyömuotoja, erityisesti tiedonsiirrossa, kuin kansallisella tasolla. Tässä tutkimuksessa tuotettua tietoa kansainvälisistä yhteistyömuodoista voidaan käyttää teollisuuden ja korkeakoulujen välisen yhteistyön kehittämiseen. Vastaavasti tässä tutkimuksessa koottua tietoa kansallisista yhteistyömuodoista voidaan käyttää kansallisen tason yhteistyön kehittämiseen.

Lisäksi tässä tutkimuksessa esiteltiin teoreettinen kuvaus tiedon kaksisuuntaisesta kulusta yhteistyöverkostoissa. Yhteistyöverkoston toiminnan ymmärtäminen edellyttää, että ymmärretään miten tieto kulkee verkostoissa. Kuvaus kehitettiin soveltaen elektroniikan piirilakeja ja piirianalyysimenetelmää mallintamaan tiedon kulkua. Kuvaus huomioi yhteistyökumppaneiden heterogeenisyyden koskien yhteistyöalan tietoja ja edelleen muodostuneita tietovirtoja. Kuvausta voidaan käyttää esimerkiksi teollisuuden ja insinöörikoulutuksen välisen yhteistyön kehityksessä.

Avainsanat:
kansainväliset yhteistyömuodot, tiedon kulku, yhteistyöverkosto, verkko, yhteistyö, insinöörikoulutus, korkeakoulutus, tietotekniikkateollisuus

1 INTRODUCTION

This study aims to find different forms of international interactions between the global information technology (IT) industry operating in Finland and engineering education and analyze the findings into larger themes.

Opportunities for people to communicate and collaborate regardless of location are being increased by the interconnected local area networks and especially the Internet. Wireless technologies further increase the ways to communicate and collaborate even on a mobile basis. Thus the relatively new ease of communication using wired or wireless broadband access in business, education and also in leisure time makes a large amount of knowledge available to an increasing number of people internationally. This also provides new options in education, marketing, collaboration and also for developing new applications in an international context.

On a general level it can be claimed that the world is covered with networks of human beings and institutions communicating with each other. The ease of communication and collaboration, nationally and internationally, makes various forms of interaction attractive. People travel more commonly to other countries for business, education and leisure as well as use social media. Ottewill, Riddy and Fill (2005, 139) define a network as non-hierarchical, a web of connections among equals. The participants, such as human beings and different types of institutions, can form nodes to networks participating in networking. Thus the participants can be members of several networks, perhaps each network having a different goal or vision. This causes networks to form networks, a network of networks (see e.g. Castells, 2001a, 10).

In parallel with increasing networking and internationalism, competition in different issues is on the increase. Globalization has been referred to as an evolving pattern of cross-border activities of a company including international investment, trade and collaboration aiming at product development, production, sourcing and marketing (Peters, 2006, 24). In the past education was mostly country-internal, and products were developed in a country for domestic use. Then country-specific support policies started to guide education and industry, and products developed and produced in one country were exported to other countries. Every country could set its policies and limit import through customs and taxation.

However, because of the integration of countries, such as in Europe, and better communication options, foreign development and production have challenged domestic development and production. The situation is that the best product of a country is not necessarily the best in Europe or in the world. Therefore, in the development and production the knowledge, labor costs, closeness of markets and availability of raw materials have become important factors. Technical knowledge, how to develop and produce competitive products, and also knowledge in business, how to manage and sell competitive products in comparison with other countries, have become especially significant. The ability to create new innovations for new products has also become an important factor for success in competition.

Collaboration between industry and higher education is gaining importance. Different countries have established different systems and policies to support national innovation generation. Furthermore collaboration between industry and higher education, mainly in research, is supported by governments. As an example, the Japanese government focused on the field of collaboration programs, and the possible forms of interactions ranged from unrestricted research grants to industrial parks where companies could establish a research team for several years in order to learn from university research (Fujisue, 1998, 380). Furthermore, local development and production together with local innovations are seen important from the perspective of the national interest. Thus many studies have been carried out from the perspective of how to develop an effective national system or environment for innovations and for increasing collaboration between industry and higher education for knowledge transfer between them. (See e.g. Wu, 2007)

However, in parallel with national attempts to increase innovation generation and increasing collaboration between industry and higher education, especially large international companies have established different types of programs to collaborate with higher education globally. Production takes place in countries which are close to the market and labor costs are relatively low. Various research and development units have been established in countries with large customer potential for the products of the company. This means that companies may develop and manufacture products in different countries for a single country or for global use, and there is no longer a single large factory developing and producing products in one country for export.

On the other hand, the national interests of different countries are unclear if companies operate in different countries having development and production in those countries. The motivation for this type of operation from companies' perspectives is to access the best of the world resources at a relatively low cost and probably close to the market. Thus the role of the government in a country receiving research and development and production is to support this new industry bringing new knowledge and funds. The role of the government of the country from which industry moves in pursuit of better resources is not so clear. Furthermore, there are also cases of direct international research collaboration between industry and foreign higher education institutions. In those cases funding for research and development can be allocated by companies to foreign higher education institutions. The role of governments in international collaboration between industry and especially foreign engineering education is unclear. Industry has become global, but so far higher education is still mainly national.

From a research perspective, there are numerous research publications related to forms of interactions between industry and higher education from a country-specific viewpoint, as can be seen in Section 2.2.1 of this study. Often there is support from government to increase collaboration between industry and higher education. On the other hand, the increasing internationalism and better ways to communicate through different types of communication networks increase the interest in international collaboration, especially between industry and engineering education, and with different motives. However, there is only little previous research on international industry-university collaboration. Because of the rapid increase in international communication and the growing tendency of companies to collaborate directly with foreign higher education institutions, it is important to research this phenomenon and the various forms of interactions to understand the possible development in international collaboration compared to the modes of interaction used on the country-specific level.

From a practical perspective, the phenomenon of global collaboration between industry and foreign higher education is still in its early phase. As can be seen in research and development, and in industrial production, the need for companies to succeed in international competition leads them also to search for new innovations and high-ability developers from abroad. Therefore this study examines international forms of interactions between the IT industry and engineering education, in order to facilitate understanding of the new development in collaboration and interactions and to facilitate further developments in collaboration.

1.1 Background to the Study

In Finland engineering education and industry have always collaborated in several ways. National borders are weakening and the roles of nations are changing, especially in Europe, and coordination and management of coordination are moving from governments to the global markets. Thus, due to this development of forms of interactions in an international direction, there is now a gap to study forms of interactions between industry and engineering education also on the international level, which this study for its part aims to fill.

Quality is a critical issue in the long-term marketing of educational products and services. This was reported by the Finnish Ministry of Education as a result of a work group appointed to create a strategy for education export. The best quality assurance method in the education business is competition, since low-quality products will not survive on the market. (Kiinnostuksesta kysynnäksi ja tuotteiksi, Suomen koulutusvientistrategia, 2010, 25) The market and industrial production and also competition in developing new applications and products are becoming increasingly international. Therefore the quality of engineering education in different countries plays an important role in the competition in applying new technologies in industrial production. Also, there is a global search for talents (Castells, 2001a, 13).

Furthermore, the Finnish Ministry of Education published an internationalization strategy for higher education for 2009–2015 to support increase in international collaboration, stating that the mobility of teachers in universities could be significantly increased by participation in international education projects or research and development projects (Korkeakoulujen kansainvälistymisstrategia 2009-2015, 29). Also research and development projects could be developed in international collaboration (Korkeakoulujen kansainvälistymisstrategia 2009-2015, 34). It seems moreover that there is an increasing desire for academics to communicate and collaborate through international networks in higher education on common issues and interests.

A reason for the choice of the topic of this study was also my personal work experience in the IT industry and engineering education. For 19 years I worked in the IT industry in several companies, holding different positions in research and development and product management, familiarizing myself with different forms of interactions to collaborate with engineering education. After working in industry, I was in charge of the Bachelor and Master of Engineering degree programs in information technology at a Finnish university of applied sciences (UAS) for seven years. The students represented many different nationalities. For the past ten years I have also been working as principal lecturer in telecommunications at a UAS. During my 10 years at the UAS I have been and also continue to be involved in the creation and development of international collaboration between industry and engineering education in the form of projects and networking. Work with international students and with the international IT industry and universities have given me valuable experience and knowledge of international interacting and networking from various perspectives.

1.2 Research Problem and Research Questions

The focus of this study is on different forms of international interactions between the global IT industry operating in Finland and engineering education in various countries.

Global collaboration and related interactions are described in the study by using the models forming the analytical framework. Castells (2004) focuses on network-form society and Gibbons et al. (1994) on knowledge production in a heterogeneous system. According to Castells (2004, 3), a network is a set of interconnected nodes, and the nodes have varying relevance for the network. This raises the question of what forms of interactions take place between nodes. In this study, nodes mean higher education institutions and international industrial companies. Gibbons's et al. (1994, 167) Mode 2 University Knowledge Production model (hereafter referred to as Mode 2 in this study) is a model of producing knowledge in a heterogeneous system consisting of multiple institutions and organizations considered nodes.

International collaboration differs from country-specific collaboration in various respects, as noted by Leydesdorff and Wagner (2008, 317):

> We suggest that international collaboration in science can be considered as a communications network that is different from national systems and has its own internal dynamics. National systems have policies and institutions that mediate scientific communication, while at the global level the network exists mainly as a self-organizing system.

Therefore the analytical framework described above is used here for the study of global collaboration networks. This study for its part aims to fill a gap in international research literature concerning forms of international interactions between global collaboration programs of the IT industry and engineering education from an industry perspective. Previous studies on forms of international industry-university interactions are few, as well as studies carried out from an industry perspective.

This leads to the research problem of this study:

What forms of interactions have been created between the information technology industry and engineering education to support their international collaboration?

The context of this study is international collaboration, specifically collaboration involving global companies operating in Finland and universities in various countries.

The scope of the study is different forms of *international interactions* between companies and universities. However, companies, universities or innovation systems themselves are not included in the scope. Also cultural aspects and other factors affecting collaboration and interaction forms are not the focus of this study.

The data of this study consists of two types of data:

1) Primary data gathered for the present study from documents of existing global collaboration programs between the IT industry and engineering education, published by companies, and interview data gathered from respondents from the IT industry and engineering education.

2) Secondary data (literature review) consisting of data collected from published articles of past studies on industry-university collaboration.

Both the primary and secondary data collected are analyzed by means of thematic analysis.

The research questions are derived from the research problem:

What are the main forms of international interactions in existing global collaboration programs and networks between the global IT industry and engineering education in contrast to country-specific forms of interactions found in existing literature?

How can the function of collaboration networks be described from a theoretical point of view to better understand the ways information flows in such networks?

Information technology is one of the fastest internationalizing fields of industry, and thus already has many established international collaboration links. Thus the new modes of operation in collaboration between industry and engineering education can obviously be first seen between the IT industry and engineering education. The need for new applications and high-ability IT professionals makes collaboration between the IT industry and engineering education attractive. For the above reasons, exploring the present forms of collaboration seems relevant and justified for further development of forms of interactions.

Many global companies have research centers and local offices in different countries. International interaction, from the perspective of this study, is taken to be interaction between industry and engineering education when interaction with industry or engineering education transcends the borders of a nation to another country. However, if an office is located in a foreign country and engaged in collaboration with local higher education, it is not counted here as global collaboration and international forms of interactions between industry and higher education. In this study the expressions industry-university collaboration and collaboration between industry and higher education are used interchangeably.

1.3 Structure of the Study

This study begins by reviewing earlier country-specific and international studies on forms of interactions between industry and higher education. The analytical framework that the study is based on is presented next. Also, some complementary theoretical aspects are discussed to enhance the view of the studied phenomenon.

After that an empirical study is carried out to find out the main forms of international interactions in existing collaboration networks. Furthermore information flows in collaboration networks are discussed to describe knowledge transfer in collaboration networks. Understanding the function of a collaboration network requires understanding the ways information flows in such a network, which typically has a heterogeneous structure.

To summarize, this study is divided into the following major chapters.

Chapter 1 introduces the topic and background, the research problem and questions, and the scope and structure of the study.

Chapter 2 starts by conceptual definitions after which previous studies on country-specific forms of interactions (secondary data) are presented and reviewed. Also the few previous studies found on international interactions are reviewed. After that the analytical framework of the study is presented.

Chapter 3 explains the study design, case selection and data collection (primary data) and theme analysis used to analyze the data. This is followed by analysis of secondary data. After that primary data is presented and analysed. The primary data consists of program data provided by IT companies in the documents of their global collaboration programs, including various forms of international interactions, and the gathered interview data.

Chapter 4 presents the results of the analyses, compares the results of the analysis of secondary data to the results of the analyses of primary data and discusses the results from various viewpoints. Furthermore the chapter includes theoretical considerations of information flows in collaboration networks.

Finally, Chapter 5 concludes the strengths and limitations and contributions of the study as well as suggests recommendations for further study.

The flow of the study is illustrated in Figure 1.

Figure 1. The dissertation structure.

2 THEORETICAL BACKGROUND

2.1 Conceptual Definitions

In the following the meanings of the key terms used in this study are specified. Also their meanings in the context of the analytical framework are presented.

In this study a *network* refers to social networks with different information flows and different amounts of knowledge in the different nodes of the network, and also in analogy to an electrical network with different currents between nodes and different voltages of nodes in the network, as discussed in Section 4.3. Since a network is defined differently in social and technical sciences, in this study a network is considered both from the social and technical sciences perspectives. Collaboration often takes the form of a network and thus the network is a key concept in the analytical framework of this study**.** In social sciences Ottewill, Riddy and Fill (2005) define a network as non-hierarchical. It is a web of connections among equals. What holds it together is not force, obligation, material incentive, or social contract, but rather shared values and the understanding that some tasks can be accomplished together that could never be accomplished separately. (Ottewill et al. 2005, 139) However, Castells (1996) defines a network as a set of interconnected nodes. Networks are open structures, able to expand without limits, integrating new nodes as long as they share the same communication codes, for example, values or performance goals. (Castells, 1996, 470) Furthermore, Edquist and Hommen (1979, 73) define a network as a special form of economic organization between markets and hierarchies. Frenken (2000, 257) states that a network can be understood as an important organizational form to coordinate the efforts of heterogeneous actors without restricting their individual goals. Some real networks, such as the World Wide Web and power grid, have a ‘scale-free’ property (Kim & Park, 2009, 8987, 8991; see also Casper, 2007) However, in social sciences a network-based social structure is a highly dynamic, open system, susceptible to innovating without threatening its balance (Castells, 1996, 470). Large companies can be said to be internally decentralized as networks (Castells, 2004, 28). Furthermore, there are also networks within large global companies and these are decentralized networks (Castells, 2001a, 2-11). In this study large global IT companies are considered to have a network form, because they have locations in several countries.

Collaboration networks are understood in this study to be networks with established linkages between different players, nodes, such as universities and companies collaborating and interacting with each other. A collaboration network can freely expand by including new links and nodes and shrink by excluding links and nodes. In this study collaboration refers to a general-level concept whereas interaction refers to a specific form of collaboration. Perc (2010, 476) states that a subset of complex networks is the social networks, of which scientific collaboration networks are an example. A social network is an account of human interactions. According to Kim and Park (2009), when the random rewiring probability of a network is low, the network is highly cliquish and its path length is short. The network made by small probability is called a ‘small-world’ network (Kim & Park, 2009, 8987). Some real networks are scale-free, meaning that some nodes can have numerous links while other nodes have only a few. A scientific collaboration network has a small-world property. An example is the Research and Development (R&D) alliance network of the biotechnology industry which is found to be a small-world network with a scale-free property. (Kim & Park, 2009, 8987) Collaboration networks are essentially undirected (Fenner, Levene & Loizou, 2007, 75; also see e.g. Cherry, Robillard, 2008).

The *information flow* in this study refers to transferring information between the collaborating network players, called nodes, such as universities and companies and is thus an important parameter in a collaboration network. According to Tomassini and Luthi (2007, 751; see also Leydesdorff and Fritsch, 2006, 1539) social networks support communication and information transmission, an information flow, in social contexts. The information flow can take one direction at a specific point in time or be bidirectional, depending on the time point researched. In this study forms of interactions in collaboration networks between the IT industry and engineering education relate closely to information flows in collaboration networks. Forms of interactions determine what kind of information and what kind of benefits the information flows in collaboration networks carry.

The *node* in this study refers to an institution, such as a university, a company or a research center, having common resources for developing applications and research in collaboration with other institutions via different links. The definition of a node belongs to the definitions of a network, referring both to a social network and an electrical network with common points of links, because a node is an important part of both types of networks. In social sciences Castells (1996, 470) defines a node as the point at which a curve intersects itself, for example national councils of ministers and European Commissioners in the political network that governs the European Union, or mobile devices generating, transmitting, and receiving signals in the global network of the media. This can be explained to mean a point at which different organizations and institutions can interact in the same way as the different components of mobile networks are connected to each other and can thus interact. Castells (1996) defines the topology by networks and determines that the distance, or intensity and frequency of interaction between two points or social positions is shorter, or more frequent, or more intense, if both points are nodes in a network than if they do not belong to the same network. On the other hand, within a given network, flows have no distance, or the same distance, between nodes. To quote Castells (1996, 470), "Thus, distance (physical, social, economic, political, and cultural) for a given point or position varies between zero (for any node in the same network) and infinite (for any point external to the network)." A node in this study refers also to a point in an electrical network where several wires meet, are connected, and thus have a common voltage. However in electronics Millman (1979, 708) defines a node as a point where two or more circuit components meet. The analogy between a closed collaboration network and an electrical network is discussed in Section 4.3.

Applied research in this study refers to applying knowledge to create new concrete applications. Stokes (1997,10) states that applied research relates to elaboration and application of the known, and the goal is to change the possible into the actual, to examine alternative ways and methods for achieving practical products. *Application development* in this study refers to development of new applications. Mode 2 knowledge production (Gibbons et al., 1994, 3), which is a part of the analytical framework of this study, is often carried out in the context of applications. According to Stokes (1997,11) development can be specified to be the systematic adaptation of research findings into devices, systems and methods after an applied research sequence.

Higher education in this study refers to the Finnish model of higher education: universities with a scientific focus and universities of applied sciences (UAS), also known as polytechnics, with a professional and applied science focus. The formal role of universities in Finland is to provide opportunities for academic research and researcher training, whereas universities of applied sciences focus on training professionals and applied research for the needs of industries (Universities Act 558/2009; Polytechnics Act 351/2003). Engineering education is a subset of higher education and means university and UAS (polytechnic) level higher education leading to bachelor's and master's degrees.

Globalization in the context of this study refers to collaboration in application development and research between institutions, such as universities, companies and research centers, over the national borders of several countries. In such global collaboration nation-states have only very limited control over policies regulating higher education. Globalization as defined by Gibbons et al. (1994, 167) is the transformation of national economies into a single international economy. On the other hand Landis (2008, 338) states that globalization can be defined and realized in many ways: it may be economic, social and cultural globalization and therefore the plural, "globalizations", is perhaps more appropriate. Economic globalization is the phenomenon of the increased integration of the world economy as evidenced by the growth of international trade and factor mobility (Castells, 1996, 413). Castells (2001a, 3) specifies, however, in the dimensions of globalization, that globalization is not only economic, but also refers to media, to information systems, to international institutions and to the networking of states. Moja and Cloete (2001) specify that in the globalizing higher education system the nation-states have limited or no control over policies regulating higher education (Moja & Cloete, 2001, 244). Furthermore, Marginson (2010) specifies globalization to refer to the making or the enhancement of global spheres of human action, including global spaces, systems, elements, identities and practices.

Globalization consists of engagement, integration and convergence on a world scale, the transformation in the organization of human affairs by linking together and expanding human activity across regions and continents. Globalization can be defined as the widening, deepening and speeding up of world-wide interconnectedness. The term world-wide can be used for the totalizing inclusive concept that takes in every global, national and local element. (Marginson, 2010, 6963) Marginson (2010) further states that while international relations across borders may involve just two nations, globalization involves many nations. Globalization is a dynamic process which is difficult to predict, drawing the local, national and global dimensions more closely together. (Marginson, 2010, 6964) On the other hand Jackson (2008) states that globalization and internationalization are dynamically linked concepts whereby the former serves as "a catalyst" and the latter is "a response in a proactive way" (Jackson, 2008, 350). (Also see e.g. Clark & Lund, 2000; Gornitzka & Maassen, 2000; Mahutga & Smith, 2011; Lothian, 2002; Castells, 2001b; Castells, 2001c; Soludo, 2001; Gelb, 2001; Chen, 2004; Gerybadze & Reger, 1999; Chesnais, 1992) Finally Väyrynen (1998, 627) defines globalization to mean an increasing autonomy of boundary-crossing financial, investment, and technology flows promoted by transnational corporations through exports, foreign subsidiaries, and strategic alliances.

The term *internationalization* is used in this study to describe small-scale activity such as interactions involving two nations. By contrast, globalization, as defined above, is used to describe large-scale activity such as collaboration involving several countries, without the control of nation-states. Moja and Cloete (2001) state that internationalization is closely linked with and dependent on autonomous nation-states having autonomous but interdependent higher education institutions (Moja & Cloete, 2001, 244). On the other hand internationalization is defined by Jackson (2008) to be any systematic sustained effort aimed at making higher education more responsive to the requirements and challenges related to the globalization of societies, economy, and labour markets (Jackson, 2008, 350; also see e.g. Carlsson, 2006; Nokkala, 2007).

An international collaboration network in this study refers to collaboration links with unidirectional or bidirectional information exchange reaching over the national borders between industrial companies and higher education institutions. A network in a global environment refers to a network consisting of participants from different countries. In the context of this study the participants of a global network consist of universities and industrial companies.

In addition, the concept of National Innovation System (NIS, also referred to as National System of Innovation) is briefly explained below because it is a fairly common concept used in the research of interactions on the country-specific level. However, the concept is not applicable in this study, which investigates interaction forms in an international context. NIS can be specified to be the system of interactions between companies, including public and private companies, universities and governments with a goal of producing science and technology country-specificly. The goals of country-specific interactions are new science and technology development, protection, financing, or regulation. (Niosi et.al. 1993, referred to in Peters, 2006, 20) Furthermore, Dill and van Vught (2010, 4) emphasized the influence of the supply of highly skilled human capital and disseminating academic knowledge on economic and social development in the industrialized nations. However, innovation systems are not included in this study. To see the effects of globalization on NIS, there has been an ongoing debate about the continued importance of a company's national base. As early as in 1990 it was predicted that national borders would disappear and thus there would be no sense to speak of country-specific competitiveness (Ohmae 1990, referred to in Peters, 2006, 25). However, also opposing viewpoints have been presented. For example, it has been argued that competitive advantage would be created and maintained through a highly localized process and the role of the state would seem to be strong (Porter 1990, referred to in Peters, 2006, 25).

2.2 Literature Review of Previous Studies on Interaction Forms

The purpose of this literature review is to present what has been studied previously related to the topic of the present study. This literature review has multiple goals. It aims to identify central interaction forms between industry and higher education emerging from past studies. Also, a goal is to justify the present study by revealing a gap in the research of the phenomenon. Finally this review groups the findings from past studies to provide the reader with an overall view of the state of collaboration studies.

The literature review has the following structure: this section includes the purpose and goal of the review, and presentation of previous studies on country-specific interaction forms by grouping them conceptually. Also previous studies including models for description of interactions are presented. The findings of the previous studies presented here form the secondary data of this study. Extensive coverage of previous studies is provided to gain a reliable view of various interaction forms used on the country-specific level of industry-university collaboration. The secondary data gathered from this literature review will be further analyzed alongside primary data for reference and comparison in Chapter 3. Presentation and discussion of the analysis results will be provided in Chapter 4 alongside the results of the analyses of primary data. (See e.g. Boote & Beile, 2005; Randolph, 2009) In addition previous studies on international collaboration are briefly reviewed in this section. However, previous studies related to international collaboration did not provide information of different interaction forms and therefore the findings of those studies are not included in the secondary data of this study.

2.2.1 Country-Specific Interaction Forms

In this section previous studies carried out in various countries on the country-specific level of collaboration and related forms of interactions between industry and higher education are presented. This secondary data was collected by conducting an electronic search of academic databases using keywords national-level interaction, collaboration networks, industry-university collaboration. The studies were published as research articles in peer-reviewed academic journals during the years 1995-2010**.** The articles included in this literature review all had the viewpoint of technology. The theoretical bases of the studies and the methodology applied were varied. The studies provided data of interaction forms used in country-specific industry-university collaboration. In the following the data extracted from the articles is integrated and described following a conceptual grouping with a focus on the forms of interactions emerging from the studies. (See, e.g. Randolph, 2009; Boote & Beile, 2005) The studies reviewed here were mostly different types of surveys conducted in various countries and no generalizations can be drawn.

Conceptual grouping of the found interaction forms

Knowledge transfer

On the basis of the studies technology transfer and knowledge transfer seem to be the main forms of collaboration between industry and engineering education. Knowledge transfer can be bidirectional and the motives of industry and engineering education in exchanging knowledge vary. Technology transfer is a term used by some researchers (see e.g. Etzkowitz & Leydesdorff; 2000, 110). However, in this study it is considered one form of knowledge transfer, transferring technical knowledge.

Technology and knowledge transfer programs appeared to have become an important form of collaboration and support for academic research and development. Furthermore students working on government-sponsored projects were more likely to be supervised by full and tenured professors. However, in the case of industry-sponsored projects the students were working with more junior faculty. Students working for industry-sponsored projects were involved in their research for a shorter time than for government-funded projects, and produced fewer publications. (Behrens & Gray, 2001, 195) For faculty involvement, reward systems might be the most critical organizational factors in university-industry technology transfer, as well as compensation and staffing practices in the technology transfer offices and administrative actions to remove informational and cultural barriers between universities and companies (Siegel, Waldman and Link, 2003, 44). University-industry technology transfer can also be seen as one process that can improve the understanding of how convergence can take place between different organizations. For example, technology transfer does not flow strictly in one direction from companies to universities or from universities to companies. Furthermore, academic researchers may benefit from better equipment and additional financial resources to conduct more experiments and get new ideas from industry scientists. (Siegel, Waldman, Atwater & Link, 2003, 130)

Universities and industry seemed to use various channels for knowledge transfer. The channels varied in the intensity of personal relations, in the types of knowledge transferred and also in which direction the knowledge flew. For industry the various channels in knowledge transfer represented different strategies to research efficiently and allowed access to different types of knowledge in different stages of innovation. Technical sciences and R&D intensive manufacturing industries tended to use direct research cooperation intensively. The R&D resources in industry and orientation of science towards industry did not seem to limit knowledge interaction. (Schartinger, Rammer, Fischer & Fröhlich, 2002, 325) Knowledge transfer channels between universities and industry may be developed so that companies define their own strategy of interaction with a university after identifying present and future knowledge needs. It was found that there were two major patterns of interaction for companies planning to be innovators or early adopters. One strategy was to focus on collaborative and contract research to support the adoption of independent knowledge. Another strategy was more focused on patents, licensing and specific organized activities to support access and adoption of systemic knowledge. (Bekkers & Freitas, 2008, 1848)

Technology transfer programs also appeared to make money for some institutions and provided many benefits to their local communities. However, many smaller university-technology transfer programs had existed 5 to 10 years and had not transferred a sufficient amount of technology for a profitable royalty stream. Many universities did not operate their programs for profit, but instead many considered technology transfer a necessary administrative function to increase the number of faculty members engaged in research with commercial potential. (Trune & Goslin, 1998, 203)

Also structural and efficiency factors affecting technology transfer were considered in various studies. The findings of a study by Anderson, Daim and Lavoie (2007) indicated that there was a wide variety in technology transfer efficiencies. However, a simple explanation, such as a public versus private educational institution, and the location of the institution did not explain the variation in technology transfer efficiencies, and therefore additional characteristics should be studied, such as faculty incentive systems. (Anderson et al. 2007, 316) In another study it was found that technology transfer was principally between inventors and contacts in the company community, and the contacts existed prior to transfers. Furthermore a remarkable proportion of transfers of new technologies from universities to private companies went to large established corporations. However, most small companies in the study were created by the inventors themselves for selling new developments in their spare time. (Harmon, Ardishvili, Cardozo, Elder, Leuthold, Parshall, Raghian & Smith, 1997, 431-432) Forms of interactions between universities and entrepreneurial companies seemed to differ from interactions between universities and large established companies. The forms of interactions appeared to be industry-sponsored contract research, consulting, licensing of technology and university involvement in technology development and commercialization. (Shane, 2002, 550) Also, companies with mechanistic structures and stable direction-oriented cultures and those which seemed to be more trusting in their university partner were more likely to institutionalize knowledge transfer activities. (Santoro & Gopalakrishnan, 2000, 312)

Furthermore, university involvement in technology transfer does not seem to result in a reduction in the quantity and quality of basic research (Siegel, Waldman, Atwater & Link, 2004, 141). Due to their mission, universities do not provide industry with readymade new product technologies (Motohashi, 2005, 593). In industry-academia relationships there may be constraints decreasing the efficiency of collaboration, because of differences in purposes, cultures, procedures, incentives, and value systems (Bucher & Jeffrey, 2005, 127, 1274).

In a study examining priorities in collaboration, educational activities were found to be given the first priority in collaboration by institutions. The second priority was given to informal informational activities and research activities. Less important was consulting, related to utilization of technical facilities. The two most important single educational activities were contacts with staff formerly employed in the business, and also thesis projects in collaboration with companies. The universities of applied sciences research activities had a higher priority than informal informational activities. (Arvanitis, Kubli, Woerter, 2008, 1870 - 1871) An example of educational activity is the following example of curriculum development. The Tokyo University of Technology had designed a curriculum with an agency for game development by industry-university collaboration in Japan. The curriculum consisted of added courses to the traditional faculty curriculum combining lectures and exercises. This was new in the field of game development in Japan. Universities collaborate with industry and play a key role in the development and evolution of the game industry. (Mikami, Watanabe, Yamaji, Ozawa, Ito, Kawashima, Takeuchi, Kondo & Kaneko, 2010, 791, 798) Another example is an introductory course on software engineering delivered by the University of Queensland for Boeing Australia Limited. The course objectives were to provide a common understanding of the nature of software engineering for company personnel and to ensure that company employees understood the practices used throughout the company. (Carrington, Strooper, Newby & Stevenson, 2005, 29) According to Hoye and Pries (2009) interactions between industry and higher education appeared to include offering of seminars, courses and workshops to industry both on-campus and at company nodes, conducting contract research for industry, consulting with industry, participating in trade conferences and expositions attended by industry representatives and/or the users of technology, doing sabbaticals in industry, participating in committees and professional groups that also included industry, maintaining informal communication with contacts developed by these means, and maintaining contacts with students and colleagues who had moved to industry. (Hoye & Pries, 2009, 686)

Research collaboration was discussed in a study between universities and the extra-university research sector. Co-authorship within the extra-university sector was not typical. The motivation of scientists to collaborate was primarily to expand and improve their research capacity, to benefit from institutional complementarities and to increase their visibility within the research field. Interaction forms also included recruitment of research staff, support for job mobility, research leadership and funding. Flexible funding allocation mechanisms were used for inter-institutional collaboration. (Heinze & Kuhlmann, 2008, 897)

However, also some negative issues were considered in the studies. Several factors appeared to affect technology and knowledge transfer causing friction and conflict or even be a barrier to collaboration (See Siegel, Waldman and Link 2003, 44; Lee 1996, 860; Siegel, Waldman, Atwater & Link, 2003, 130; Bruneel, D'Este & Salter, 2010, 866). It was found that such an issue is for example the intellectual property right (IPR). (Siegel, Waldman and Link, 2003, 44) Also, a barrier to collaboration between universities and industry may be the university's long-term orientation (Bruneel, D'Este & Salter, 2010, 866). Universities are not often concerned about time schedules whereas for companies time schedules are typically critical. It has even been argued that barriers related to intellectual property have become more common in interactions between universities and industry because universities increasingly commercialize research (Bruneel, D'Este & Salter, 2010, 866). Furthermore, the IPR issue may cause conflict because universities and companies have different perspectives and goals regarding intellectual property (Siegel, Waldman, Atwater & Link, 2003, 130). A barrier also seemed to be cultural differences between university and industry and the need for finance for further development (Decter, Bennett & Leseure, 2007, 151).

Collaboration may also cause fears. The fear of negative consequences, possibly resulting from too close collaboration between industry and university, was found to be the most decisive factor in the shaping of faculty attitudes toward transfer. The less the fear of intrusion was, the greater was the support for transfer. However, the greater the fear was, the less there was support. The faculty in applied disciplines were found to be much more supportive of various transfer alternatives than their colleagues in the basic and social sciences. (Lee, 1996, 860; also see Siegel, Waldman and Link, 2003, 44)

Finally in university-industry technology transfer it may be difficult to support multiple social goals simultaneously. Technology transfer may also cause tension between the university departments which are successful and those which are unsuccessful in technology transfer. No-one has greater knowledge about a technology than academia, and technology transfer can in this way accelerate the route to the market. (Nicolaou & Birley, 2003, 352)

Networking and links

Collaboration between industry and higher education may be in the form of networking, and various links are generated between the collaborating parties. Collaboration is successful because of shared goals, planning, mutual trust, effective communication, patience, and hard work. Universities and industry have traditionally collaborated in informal ways such as student internships, faculty exchanges and industry capstone projects. However, formal collaboration between industry and higher education has been increasing. (Mead, Bekman, Lawrence, O'Mary, Parish, Unpingco and Walker, 1999, 155, 160)

To develop stronger links with industry, some higher education institutions in some countries have established science parks. Higher education institutions, are an important resource network for high technology companies. The formal and informal links developed with local higher education institutions by independent science park companies were compared by Westhead and Storey (1995) with the links developed by a comparable group of independent high technology companies not located in the park. The types of links between higher education institutions and science park companies included for example informal contacts with academics, employment of academics on a part-time or consultancy basis, access to specialist equipment, student projects, employment of new graduates, training by higher education, and assistance from industry in teaching higher education programs. The most active links among *science park companies* in order of activity were found to be informal contacts with academics, access to specialist equipment, employment of academics on a part-time or consultancy basis, and employment of new graduates. (Westhead & Storey, 1995, 353) For comparison, the most active types of links among *off-park companies* in order of activity appeared to be informal contacts with academics, employment of new graduates, access to specialist equipment, and employment of academics on a part-time or consultancy basis. Companies located in a science park were significantly more likely to have links with a local higher education institution and have more links than off-park companies. (Westhead & Storey, 1995, 353, 358; also see Lee & Win, 2004, 435-436; Philpott, Dooley, O'Reilly & Lupton, 2010, 2) In particular, science parks as a mechanism for interaction between universities and industry seemed to make it possible to establish informal links. Short distances between science parks and universities were seen to improve their interactions. (Vedovello, 1997, 501)

Regarding the effect of university-industry collaboration on the innovative performance of companies, a study was carried out on companies operating in the advanced materials field in Japan. The study showed that the official channels, by providing patent licenses, seemed to play a limited role in knowledge flow between universities and industries. However, open channels, such as academic paper publication, consulting and the provision of scientific advice occurring informally between academic and corporate scientists, played a critical role in knowledge transfer. (Baba, Shichijo & Sedita, 2009, 763) Furthermore, regarding institutional policies for university-industry links in Japan, it was found that five factors might influence university engagement with industry: the range of organizations involved in university-industry links, personnel issues, policies on university-industry links, incentive systems, and institutional background and development. (Woolgar, 2007, 1271)

The issue of faculty member participation in industry-university collaboration was considered in some recent studies but the results were somewhat contradictory. Networking within one's own faculty and with academic colleagues seemed to have the greatest impact on academic careers, and collaboration with industry showed no relationship to academic rank. The networks on different levels were related, implying that when the threshold of networking had been reached, interactions were easier. Resources seemed to stimulate researchers who could gather experience at many universities and work in a dynamic scientific field. However, the impact of these factors may depend on the network. (Rijnsoever, Hessels & Vandeberg, 2008, 1262) However, in a study by Azagra-Caro (2007, 712) it was also found that there were two types of faculty members who were usually in contact with companies: males and those in administrative positions, and the contacts were mainly with larger companies outside the region. On the other hand, Guiliani et al. (2010) stated that academic researchers with more links to industry were often young, female and important in their academic research system. Young scholars might feel that such an orientation would be rewarding from the professional perspective. (Giuliani, Morrison, Pietrobelli & Rabellotti, 2010, 757) There are very few similar relationships between industry and universities. In the technology-oriented disciplines researchers in the best departments had a high industry involvement. (Perkmann, King & Pavelin, 2011, 12)

The interest of companies to collaborate with universities appeared to depend on various factors. The satisfaction with collaboration between university and industry was found to depend on the ability of university and industry to build capabilities in human resources, technology, equipment, positive attitudes to and understanding of the differences in the relationship. Collaboration also required commitment from the industry and university sides. (Sugandhavanija, Suchai, Ketjoy and Klongboonjit, 2010,8) For example in France, companies had little need to develop relationships with universities, because they had close involvement with public laboratories. On the other hand, in the UK mobile engineers, when changing jobs, enhanced interactions and brought new university contacts. The important factor driving a relatively high level of enterprise-university interactions turned out to be severe financial constraints in UK universities, making academic departments identify potential new sources of income in the form of industrial research partners. (Mason, Beltramo & Paul, 2004, 69) Two types of networking between higher education and companies were found to exist in China: hard and soft networking. Hard networking referred to national networks for technology transfer. The transfer was approved by the Chinese Ministry of Education and initiated by the main research universities Tsinghua, Beijing, Fudan, Nanjing, Zhejiang, Shanghai, Jiaoda and Xia'an Jiaoda. Soft networking referred to a close (formal or informal) relationship between a higher education institution and companies. (Hong & Yunzhong, 2001, 181)

Linkages between relationship intensity and tangible outcomes in industry-university collaborative ventures tended to produce higher levels of tangible outcomes at higher levels of industry-university relationship intensity. Higher levels of tangible outcomes generated in the past served to stimulate higher levels of industry-university relationship intensity in the future. Furthermore the strong two-way linkage between relationship intensity and tangible outcomes indicated spiralling interaction. Also geographical proximity played an important role in the intensity of industry-university relationships and the generated tangible outcomes. However organizational size and length of relationship had little effect on dynamics. In addition, Santoro (2000, 267-268) argued against the notion of a model where basic research always precedes applied research. Links between industry and higher education are important for collaboration. The links usually are connections between people, but can be also electrical. An electrical link can be a laboratory network used by companies and higher education for experiments and demonstrations (Lovrek, Kos, Mikac, 2003, 451). The reason to establish links is to gain new knowledge. It was found that companies connecting systematically to sources of knowledge become more competitive (Jensen, Johnson, Lorenz, Lundvall, 2007, 690). Interactions with universities stimulate companies' innovativeness compared to companies staying in routines (Kaufmann, Tödtling, 2001, 802). The best channels for interactions were found to be those providing companies with long-term benefits (Fuentes, Dutrenit, 2012, 14). The role of universities as knowledge generators in developing countries varied by country and changed depending on the economic development in a country and thus different forms in university-industry relationships could take place (Eun, Lee, Wu, 2006, 1343). Regarding science park companies it was found that a link with a local university was more likely established than with a company outside the science park (Löfsten, Lindelöf, 2002, 859).

In the development of competitiveness in the global economy many countries build a competitive economy capability. One popular approach is to support university-industry knowledge exchange linkages (Acworth, 2008, 1241). Laurensen and Salter (2004, 1212) found that such relationships were valuable for innovations, because universities could be considered to be direct knowledge sources for innovation. Tether and Tajar (2008) also stated that links with specialist knowledge providers complemented rather than replaced a company's own innovation activities, and also links with knowledge providers complemented a company's information sourcing (Tether & Tajar, 2008, 1092). If there were a sufficient number of regional companies as members seeking to develop linkages with universities, for example in Japan intermediary organizations were found to be effective and needed (Kodama, 2008, 1238). In addition Perkman and Walsh (2008) studied development from three viewpoints. First, commercialization-driven consulting made companies accelerate development along a chosen path of in-sourced technology. Second, research-driven consulting was mainly for large companies and research-driven sectors, and third, opportunity-driven consulting was mainly for new-technology based companies to acquire more expertise. (Perkman & Walsh, 2008, 1889)

University-industry cooperation spreads the applications of scientific and technological innovations. The national innovation system and the innovation environment shape the vitality of research universities and spin-off companies (Wu, 2007, 1089). Compared to medium-sized manufacturers, small companies acquire less innovation-related information from their competitors, suppliers and research institutions and have more limited access to external knowledge for projects (Cohendet & Meyer-Krahmer, 2001, 1585). Universities are a source of innovation, and the more companies use knowledge generated at universities, the more the economy of the region grows (Mueller, 2006, 1506). The government assistance may be necessary in regions where, due to lower levels of R&D and economic activity, strong regional effects may lead to a situation that universities are less efficient in commercializing technology (Chapple, Lockett, Siegel & Wright, 2005, 381). However, due to the characteristics of knowledge or mode of knowledge transfer, industry-university cooperation may not directly affect success in innovation in a company, but may affect decision-making or the management of research projects (Eom & Lee, 2010, 637). In partnership projects between industry, academia and government organizations the participants bring different objectives, knowledge, contributions and modes of absorbing benefits. Therefore the knowledge produced will be diffused and used differently in those organizations. (Carayannis, Alexander & Ioannidis, 2000, 487) Competition and collaboration between two institutions could affect other institutions in industry. The collaboration-competition duality taking place in networks is evident. (Oliver, 2004, 167) The main motive of companies to collaborate with universities is that the technology available worldwide is too general to achieve market leadership in future projects, partly because the knowledge and manpower are lacking (Phabhu, 1999, 499).

Companies that actively scan their environment and voluntarily disclose internal competencies have a tendency to collaborate with academics. However, the views of public research organizations and companies are highly heterogeneous. (Fontana, Geuna & Matt, 2006, 321) Some university-industry links are more valuable because of the different potential for knowledge diffusion of the companies of the link (Giuliani & Arza, 2009, 916).

Furthermore, in a two-case study of multi-discipline inter-institutional collaboration it was found that a relatively high level of development was necessary to run collaboration (Corley, Boardman & Bozeman, 2006, 975). One way to organize the collaboration was found to be working communities, for example faculties inviting experienced people from outside higher education to lecture for professors, students and professionals from industry (Landsberg, 1985, 32; also see e.g. Daghfous, 2004; Leydesdorff & Besselaar, 2000; Kirkland, 1992).

Research and Development

Research and development (R&D) is an important form of collaboration between industry and engineering education, because knowledge transfer is closely focused on the same goal. Especially different programs and projects for developing new applications are typical.

New technology seems to be one of the reasons for companies to collaborate with universities so that they could harvest new technologies and keep their competitive edge. It was found that expansion of the research agendas of universities to companies, including the science and technology demands of companies, would increase linkages. Companies interacting with universities could improve their innovative ability and capacity. In cases where companies did not have R&D resources in their organizational structure, they had no opportunities to link up with universities. (Vedovello, 1998, 216)
In another study on university-business-technology transfer it was found that access to new ideas and technologies was a primary motivation for companies to cooperate with universities. Other motivations of less importance were reduction of R&D costs and

greater speed to the market with a new technology. (Decter, Bennett & Leseure, 2007, 151)

Furthermore the impact of research universities and companies on technological innovation in industry can be seen as strong support, especially together with long-term strategically planned research programs (Feller, Ailes & Roessner, 2002, 473). Contract research between a university researcher and a company typically involves applied research. This is beneficial for companies, since they can secure knowledge enhancement for their own scientific workforce. (Wright, Clarysse, Lockett & Knockaert, 2008, 1207) It was found that joint development of innovations between universities and companies had two main factors, which were complementary technological competencies and long-term and lasting collaboration relationships. An interesting finding was that high quality of universities was found to be a more important factor than geographical closeness. (Petruzelli, 2011, 9) However, to maximize the ability of a company to strengthen its innovation activities through research and development interactions with public institutions, the research environments should, as a finding of another study showed (Broström, 2010, 1319), be at a reasonable distance.

Also, the role of universities in the knowledge economy will become more important, and linkages with companies will start to multiply in industrialized and industrializing countries. The reasons for this are for example that companies are committing to product and process innovation to sustain their competitiveness, to enhance returns and to diversify into market niches. Also, dynamic firms of every size are turning to new opportunities arising from scientific advances. Furthermore universities with research capabilities may seek ties with business to diversify their sources of funding. A reason might also be the encouragement and incentives of governments to the university sector in an effort to expand the research function. (Yusuf, 2008, 1168 – 1169; also see e.g. Sakakibara, 2000; Rosell, Agrawal, 2009; Jacob, Lundqvist, Hellsmark, 2003; Bercovitz, Feldman, 2007; Jha, Welch, 2010)

Personal relations as an influencing factor in collaboration as well as attitudes of collaborating academics and students have been studied. Intense R&D collaboration is based on strong personal and organizational relationships. (Barnes, Pashby & Gibbons, 2006, 404) It was found that academics who collaborated because of research content and reputation could benefit more from the collaboration than academics collaborating to maintain or increase funding (Carayol, 2003, 905). Many researchers recognized that cultural differences were once a barrier to collaboration but now they were experiencing that institutional logic was converging during projects (Bjerregaard, 2010, 106). Also scientific reputation and university culture were found to influence university-industry collaboration in a positive way (Azagra-Caro, Archontakis, Gutierrez-Gracia & Fernandez-de-Lucio, 2006, 53-54). Furthermore the R&D intensity of companies seemed to be related to possibilities to access highly skilled personnel, which would increase collaboration (Bishop, D'Este & Neely, 2011, 38). However, female academics tended to cooperate less in R&D than male academics. All in all, R&D collaboration seemed sensitive to gender, discipline, interest in R&D and to direct encouragement by university. (Azagra-Caro, Archontakis, Gutierrez-Gracia & Fernandez-de-Lucio, 2006, 53 - 54)

In a study related to student perceptions of successful and unsuccessful collaborative projects, three factors affecting success were identified: supervision, project management, and communication. Frequent project meetings, which were found to correlate with success, were one possible strategy to handle social relationship challenges to effective collaboration (Butcher & Jeffrey, 2007, 1248).

However, the literature provided no information on how to manage collaboration between industry and university. Contract research would need a well-balanced process for management and monitoring in industrial innovation. This should include the necessary know-how and processes for legal, financial and human resources management issues. The people supporting the process should be professionals. A knowledge management policy including patent funding mechanisms and professional intellectual property management would also be needed as well as access to seed funding. (Debackere & Veugelers, 2005, 339 - 340)

Forms of interactions between university and industry might depend on the objectives of collaboration and assume many forms, such as research contracts and establishment of research centers. In a study on university researchers working with private companies, there was very little evidence found of conflicts between industry and academic roles in interactions. Scientific norms were not in contradiction with commercial activities. (Boardman & Ponomariov, 2009, 151) For example a contract would be made between the university research center and a contractor and the share of the costs would be agreed in the contract. The joint R&D venture would cover activities from R&D to commercialization consultancy. Industry might commercialize the invention by licensing. Licensing means transferring less-than-ownership rights to intellectual property, and the receiving party is entitled to use the intellectual property. (Lee& Win, 2004, 435 - 436) University research center scientists involved in applied and commercially relevant research were likely to interact with private companies (Boardman & Ponomariov, 2009, 151). Furthermore, in a study on nanotechnology transfer from universities to firms and related interactions in the Finnish nanotechnology community, the most frequent mode of interaction was found to be conferences and seminars. Public R&D projects and bilateral R&D projects were the next most common interactions. Other interactions found in the study were consulting companies' R&D, joint publications, supervision of theses, lectures tailored to companies, joint research or other facilities and working in companies. (Nikulainen & Palmberg, 2010, 7)

University research centers sponsored by government seemed to increase the industry involvement of academic researchers (Boardman, 2009, 1515-1516). Academic researchers on research grants and contracts worked more extensively with companies than academic researchers without grants and contracts. Having more grants increased the intensity of working with industry, and scientists on industry contracts interacted more with industry than scientists funded by governments. (Bozeman & Gaughan, 2007, 704)

Publications

Publications are an important outcome of academic research. However, while the operation of research units is often measured in terms of the numbers of publications, industry is typically interested in new applications and possible patents. This sometimes leads to different priorities in collaboration between industry and engineering education.

Furthermore, it was found that industry-university collaboration was identified through co-authorship of scientific articles and no significant differences were observed in papers co-authored by private companies (Abramo, D'Angelo, Di Costa & Solazzi, 2009, 506-507). In a study regarding publications, inventors who were often involved in patenting published more in scientifically oriented journals than their colleagues not involved in patenting. The exception was in applied engineering where inventors published in more technically oriented journals. (Looy, Callaert & Debackere, 2006, 605) In addition, involvement in contract research seemed to stimulate the scientific activities of divisions, resulting in greater publication output. No trade seemed to have occurred between entrepreneurial and scientific activities in the divisions researched. (Looy van, Ranga, Callaert, Debackere & Zimmerman, 2004, 439; also see e.g. Crespi, D'Este, Fontana, Geuna, 2011)

Industry-University-Government Networks

In the following, an analytical model, the Triple Helix model of university-industry-government relations, is briefly described. The model is described in this section to provide an additional viewpoint to the arrangement of collaboration between industry and universities. However, the model is not part of the analytical framework of this study where the focus is the different forms of interactions, not participants in collaboration, nor dynamics or arrangements among them.

The Triple Helix model was developed to describe the dynamic relations among the different functions of university, industry and government, such as knowledge production, diffusion and control (Leydesdorff & Fritsch, 2006, 1539). In this section, previous studies related to country-specific collaboration and related forms of interactions have been described and thus the Triple Helix model is discussed in this section.

The Triple Helix refers to both the relationship of university, industry and government and the internal transformation within each of these sections (Ezkowitz & Leydesdorff, 2000, 118). The Triple Helix is an analytical model which makes it possible to specify relevant categories for observation in terms of expectation. The system studied can be expected to remain in transition and thus observations have to be evaluated statistically (Leydesdorff & Meyer, 2006, 1445; also see Hatakeyama & Ruppel, 2004, 537-538). However, a national innovation system can be considered a system of interactions between companies, universities and governments with concrete country-specific goals (Niosi et.al. 1993, referred to in Peters, 2006, 20). In the Triple Helix model the university can take a strengthening role in innovation in knowledge-based societies. There is a difference to the national systems of innovation approach, where the company can take the leading role in innovation. Furthermore there is also a difference to Sabato's triangle model where the state takes the leading role. (Ezkowitz & Leydesdorff, 2000, 109)

Leydesdorff and Meyer (2006) specified the Triple Helix model as wealth generation (industry), novelty production (academia), and public control (government) (Leydesdorff & Meyer, 2006, 1441). In the Triple Helix model there are three elements: industry, university and government, and between these elements there are three interfaces where the interaction can take place. The information flowing at the interfaces is not just one-way, but collaboration and interactions between universities and companies create two-way knowledge flows (Balconi & Laboranti, 2006, 1616). When considering the functions of the three interfaces of the Triple Helix system (Leydesdorff and Meyer 2006, 1441) from a country-specific perspective, there may be one university, one government and some companies. The companies may be global companies or newly established companies, small or large. The local university carries out research projects and the results of the research may be used by local companies and new enterprises for developing and manufacturing products. Additionally, the companies recruit university graduates and collaborate with the local universities in various ways.

Etzkowitz and Leydesdorff (2000) presented the evolution of innovation systems and university-industry-government relations using the Triple Helix model in three configurations, Triple Helix I- III, which are policy models. In the first configuration, Triple Helix I, the nation-state encompasses academia and industry and directs the relation between academia and industry. (Etzkowitz & Leydesdorff, 2000, 111) However, in developing societies knowledge has been a monopoly of the nation-state, and the education system has been defined by the state, and research and development has been mainly pursued in state-owned companies. In the globalized information technology environment the control of knowledge by the nation-state is reduced. (Carnoy, 2001, 31) On the national level the government to some extent funds industry-university collaboration and thus at the same time has partial control over the collaboration and information flows. However, when industry and engineering education collaborate without government involvement, such as in industrial global collaboration programs, government has almost no control over information flows. Furthermore, in the first configuration developed by Etzkowitz and Leydesdorff (2000, 111), the state encompasses the interactions between industry and academia. In the second configuration, Triple Helix II, there are separate institutional spheres, state, academia and industry. The state does not seem to encompass academia, industry and their relations in this model. The relation between academia, industry and government in this policy model is more autonomous than in the state-encompassed model. (Etzkowitz & Leydesdorff, 2000, 111) In the third configuration, Triple Helix III, the institutional spheres are overlapping and forming hybrid organizations, each taking the role of the other organization at the interfaces. Most governments try to apply this form of policy. This set-up is often encouraged by government through financing. The Triple Helix does not only mean the relationship of university, industry, and government, but also the internal transformation of each player (Etzkowitz & Leydesdorff, 2000, 111).

Studies of the applicability of the Triple Helix model

The applications of the Triple Helix model (Leydesdorff & Meyer 2006, 1441) in some example countries presented in various studies are discussed below to widen the horizon on the collaboration and interactions on the country-specific level, related to the secondary data of this study. However, the Triple Helix model is not sufficient to describe international interactions in global collaboration (see Section 1.2; Leydesdorff & Wagner, 2008, 317). Therefore, to provide theoretical background for the study of primary data, more applicable theories are used as the analytical framework in this study (Section 2.3).

In Finland Hölttä (2010) studied the education and research system and stated that the Government of Finland has a comprehensive role in the policy design and implementation of the Finnish education and research system. However, a trend has been the transition from a very highly centralized and controlled university system in a decentralized and deregulated direction. Research and higher education are seen as the most important part of the national innovation system of Finland. (Hölttä, 2010, 208-211; see also e.g. Hautamäki & Oksanen, 2012)

Furthermore, Mok (2005) studied the changing role of government and higher education governance in Hong Kong and found that the role of Asian governments has not necessarily weakened. The government is a part of the network and in a coordinator and facilitator role to increase entrepreneurship with the university, business and industry. The conventional university mission, with a focus on teaching and research is shifting towards entrepreneurial universities by including applied research and professional teaching. The universities have to work more closely with industry, business, and commerce to make modern universities not only more entrepreneurial, but also more applied and professionally oriented to follow rapid social and economical changes. (Mok, 2005, 551-552)

However, Park and Leydesdorff (2010) studied collaboration in Korea, where universities and industries have developed nationally and internationally in recent decades. This has led to control problems on the national level and government intervention can no longer control these developments. The Korean government wants to improve university-industry relations for strengthening Korea's innovation system. Hence the new Korean government programs are based on differentiation among three sectors of the research system: academia was stimulated to develop according to the international criteria for publications and citations, industry is no longer tied to the national knowledge base, and the project-based system in public research is used to generate commercially viable technologies and innovations. Therefore, the differentiation makes the integration in Triple Helix relations become less central. (Park & Leydesdorff, 2010, 640, 647 - 648)

In Hungary Inzelt (2004) studied the applicability of the Triple Helix model and found that new government measures are attempting to improve the innovative attitude of business enterprises and to connect the main actors. However, only a limited number of companies are actually interested in university-industry interactions. Hungary resembles other less advanced countries where companies have a weaker capacity to create, screen, encourage and incorporate new knowledge. The problem is that small and micro-firms in Hungary need expertise in their environment, but universities and research organizations are not interested in collaborating with them. The scattered type information showed that those types of interactions representing an arm's length or the Triple Helix pattern have penetrated into Hungary. (Inzelt, 2004, 993)

The interactions in Japan were studied by Fujisue (1998). By law the Japanese government focuses on the field of collaboration, the Liaison Program, which is a mid-term sponsor commitment and has little relevance to a company's research. The possible interactions range from unrestricted research grants to industrial parks where companies can establish a research team for several years to learn from university research. Somewhere mid to long-range lies the industry-sponsored contract research interaction including academic research centers, research agreements and university-based consortia. The Japanese government's next step should be long-term and high-relevance fields of technology parks close to universities, university-based consortia and research agreements between industry and university. (Fujisue, 1998, 380; see also e.g. Hayashi, 2003)

Some further aspects have been raised related to the application of the Triple Helix model. When universities become entrepreneurs, they do not give up the functions of teaching and disinterested research (Etzkowitz, 2003, 120). In addition Benner and Sandström (2000) discussed the issue of what makes possible or hinders the development of new forms of knowledge production. For example academic research seems to move with openness also towards practical applications and commercial use of academic research (Benner & Sandström, 2000, 291). Furthermore, innovation is a combination of relations and interrelations between universities, industry and government. There must also be numerous institutional combinations produced by network relations, communications and mutual exchanges. (Marques, Caraca & Diz, 2006, 541)

To summarize the above examples, the role of the government in Korea has been very important for the development of universities and industry. Internationalism brings problems and Triple Helix relations become less central. In Finland there has been a trend from a centralized and controlled university system in a decentralized and deregulated direction. On the other hand in Hungary industry has a poor capability to absorb new knowledge, interest in collaboration between industry and universities is weak, and information is scattered. In Japan the government should next establish science parks to intensify collaboration between universities and industry. This is for the representatives of companies to learn from the research of universities. Common to all these countries is the relatively strong role of government in facilitating collaboration between industry and higher education. Differences are in the different extent of government involvement in collaboration.

However, the Triple Helix model is not applicable in the context of this study which is global collaboration networks. In global collaboration governments compete with one another of the lead in collaboration and thus we do not know which government governs in global collaboration. Also, in global collaboration the role of governments can be considered small but global competition and the driving force of the market seem remarkable. The Triple Helix model is one model to study country-specific network arrangements between university, industry and government, but because of the focus of this study on international forms of interactions, the Triple Helix model was not selected for analysis of network arrangements in this study. Therefore primary and secondary data are analyzed in view of the analytical framework of this study, discussed in Section 2.3. Furthermore, there does not seem to be previous literature related to forms of interactions where the Triple Helix model had been used in an international or global context.

Models of country-specific interactions

Earlier in this section previous studies on country-specific interactions were examined and the found forms of interactions were conceptually grouped. In the following, previous studies on country-specific interactions, including the original authors' classifications, are reviewed.

First D'Este's and Patel's (2007) classification of university-industry interactions in distinct categories is presented. In addition it is discussed in relation to some examples from the Finnish engineering education and industry based on my experience, to illustrate university-industry interactions, as classified by D'Este and Patel, with real-life examples. After that Geiger's (2004) four kinds of interaction are considered. Then Meyer-Krahmer's and Schmoch's (1998) model of university-industry interactions in four fields in science-based technologies are introduced as a third viewpoint. Finally Santoro's and Chakrabarti's (2002, 1164 - 1165) the concept of four important I/U relationship alternatives is discussed. D'Este and Patel's (2007, 1300-1301) analysis was based on survey data as well as Meyer-Krahmer's and Schmoch's (1998, 835 - 851) analysis. However, Geiger's (2004, 195 - 196) analysis of interactions was based on economic data. Santoro's and Chakrabarti's (2002, 1169) study was based on program evaluations, survey data and interview data.

D’Este’s and Patel’s classification of university-industry interactions in distinct categories

University-industry interactions were classified by D’Este and Patel (2007) and their analysis was based on a survey of UK academic researchers and patterns of university-industry interactions. Nine types of interactions were categorized into five categories: meetings and conferences, consultancy and contract research, creation of physical facilities, training and joint research. (D’Este & Patel, 2007, 1300-1301) D’Este and Patel (2007) researched different channels through which researchers interacted with industry and also the factors that influenced the researchers’ engagement in interactions. The variety and frequency of interactions were also explained. (D’Este & Patel, 2007, 1295)

Meetings and conferences was the first form of interactions (D’Este & Patel, 2007, 1301). In meetings and conferences specialists from industry and higher education meet and can exchange information. Such forms of interactions are informal. Papers are prepared and published in a specific academic field and presented in conferences. The scientists may have different backgrounds, such as postgraduates, postgraduate students, industry-funded research team members and also members of other interest groups. The common interest in the academic field gathers the researchers together to meet and present papers. Researcher meetings and conferences are also forums for experienced and junior researchers to meet. Meetings and conferences are becoming increasingly international and researchers come from different institutions and companies and from many countries.

Consultancy and contract research was the second form of interactions (D’Este & Patel, 2007, 1301). Such forms of interactions are formal. As an example, the consultancy and contract research in Finnish engineering education takes different forms depending on the higher education institution and its knowledge related to the field of technology, experience in the field and resources in the science researched or developed. Research requires academic training, and in UASs contract research is mostly contract development. The creation of physical facilities was the third category of interaction between higher education and industry (D’Este & Patel, 2007, 1301). Such form of interaction is formal. For example, the creation of physical facilities such as incubators for new start-up companies is typical in Finnish engineering education institutions.

Training in companies was the fourth category of interactions (D’Este & Patel, 2007, 1301). For example, in Finland training as a form of interaction between higher education and industry can be considered to be informal, because in Finland students and lecturers make the contract for training directly with industry. In a Finnish UAS, an industrial placement during studies in an applicable field of technology is a mandatory part of the bachelor’s degree. However, in engineering education at universities in Finland there is no training requirement. The training period in industry gives students an opportunity to familiarize themselves with their specific field of industry. During the working periods in industry students get to know companies. The industrial placement period also gives a good opportunity for industry to recruit high-ability students. Industrial placement periods are typically done during summers, and companies pay students a salary. Additionally the trainee gets support and guidance from company employees. Often social networking with colleagues starts during the industrial placement periods, and the networking may later facilitate in finding a job after graduation. A working period in a collaboration project can be counted as training and be credited to a student.

Lecturers at UASs in Finland may also take training periods in industry. UASs allow their lecturers to take a training period in a relevant field of technology. During the training period in industry a lecturer works in a company and updates his or her knowledge and skills in the relevant field of technology and familiarizes himself/herself with the current working methods in industry. This is important because teaching in applied sciences includes plenty of laboratory exercises guided and produced by lecturers, and the courses and laboratory exercises must be updated according to the requirements of the latest technologies similar to industry. From the industry perspective such training periods increase communication between engineering education and industry. Good communication and networking make a better match between the skills industry requires of a graduate and the skills the education provides.

Lecturers of engineering at universities of applied sciences must have at least three years' working experience in the applicable field of technology to get a permanent appointment as a senior lecturer or a principal lecturer in a professional subject (Finnish Polytechnic Decree /Valtioneuvoston asetus ammattikorkeakouluista 352/2003, 1765). This mandatory requirement for working experience also constitutes one form of interaction and networking between industry and universities of applied sciences. It also gives an understanding of duties and activities in industry and improves communication and understanding between industry and UASs. The different forms of training generate many connections between industry, students and engineering education. Students and industry employees meet each other, and thus networking takes place.

Joint research was the fifth form of interactions between higher education and industry (D'Este & Patel, 2007, 1301). This form of interaction can be considered formal. In joint research or application development the project is not always totally outsourced to a university by industry, but the research or development task is performed and shared by an industrial company and higher education institution. Joint research for example in Finland, has the nature of joint development and is often in the form of a final year project. The agreement to carry out a final year project and thesis is negotiated directly between the student and the company. While carrying out this project, the student works in the industrial company and is paid for the work and time used for thedevelopment task. Supervision of the final year project is provided by the higher education institution and tutoring by the company where the final year project is carried out. Joint development, especially related to new applications, may also take place in collaboration programs and networks.

Unlike contract research, joint research usually takes place in industry and higher education facilities. The joint research or development task may be a wide-scope task in which an industrial company outsources part or parts of a research or development project to universities. Outsourcing may include innovation harvesting for applications. The new innovations developed by students may be excluded from the final industrial product, but may also be included in it, after re-engineering and productization. During negotiations of a joint development project between an industrial company and a higher education institution, a project plan is drawn up and approved by both parties. Then the project frame contract, necessary nondisclosure agreements, budget and time scale are negotiated and approved by both parties. Follow-ups and steering meetings are agreed on. Desired outcomes are also agreed on, for example documentation and a piece of software, and the collected data.

Geiger's four kinds of interaction

The enhancement function of industry-sponsored academic research in the United States was examined by Geiger (2004, 195-196). In the analysis four kinds of interaction were identified. The analysis was based on economic data. Geiger (2004, 195) states that in the traditional model the contribution of university science deliverables is less significant economically compared to intermediate contributions to stimulate and enhance industrial research and development, and so the industrial research and development could be called the enhancement function of industry-supported academic research. In many cases, the traditional model of university-industry research collaboration is not used, but research between industry and higher education can be collaborative. This interaction model is described in the following to provide an example of interactions with an economic viewpoint.

Different reasons for the reluctance of companies to invest in knowledge production were identified by Geiger (2004). The first reason is uncertainty: the more basic the research is, the greater is the uncertainty that economically valuable results will be generated and it may take a longer time to see results. The second reason is appropriateness: the knowledge becomes freely available and proprietary control becomes difficult. These reasons discourage companies from investing in basic research. There are three common ways by which companies establish control over new knowledge: trade secrets, first mover advantage, and patents. (Geiger, 2004, 194-195) Well managed research and development collaboration programs help participants to control new knowledge, and to use new knowledge and applications a participant must, for knowledge transfer, be one of the collaborating parties.

Advanced technological knowledge can mostly be used only by those who participate in research. Thus a technological firm must be plugged into the network of scientific communication in order to understand the advantages relevant to its products and to use it for new innovations. The enhancement function can be characterized by four types of interactions. (Geiger, 2004, 195-196) In Geiger’s analysis of interactions, the first type of interactions is field-intensive knowledge. For companies operating on science-based technologies, the link to the university-based scientific community is important to keep the internal research and development updated with the very latest information in the field of technology in which the company is operating (Geiger, 2004, 195-196). To apply new technologies, the company must be involved in knowledge production to understand the possibilities and limitations of the very latest technologies. The second type of interactions is field-extensive knowledge. Companies may develop complex technological systems requiring multidisciplinary expertise. In such a case academic expertise may be needed to solve the problems (Geiger, 2004, 196).

Personnel enhancement is the third type of interactions in Geiger’s analysis. Companies see universities as resource pools, places from which new researchers can be recruited. According to Geiger (2004, 196), personal contacts are effective: by knowing the person to be recruited, the risk of problems in recruitment can be avoided. By collaborating on projects, students and company employees learn to know each other, and students and graduates can be recruited by companies. The fourth type of interactions is instrumentation. In some cases universities have been a source of new instrumentation, which has been adopted by companies (Geiger, 2004, 196). In collaboration between industry and higher education in a field of such as information technology, the focus is often on application development. In other type of sciences, as in production-close sciences, the role of instrumentation may be more important. In information technology the tools mainly come from companies specialized in tool development, and the tools are then used by higher education and other companies in applications.

Meyer-Krahmer's and Schmoch's science-based technologies: university-industry interactions in four fields

The relationship between industry and universities with a focus on Germany and interactions with industry was studied by Meyer-Krahmer and Schmoch (1998, 835-851). Their analysis was based on a survey. The survey was conducted in four academic fields, three science-based fields and one less science-based field for reference. Meyer-Krahmer and Schmoch (1998, 840) asked professors to assess the different interaction types according to the importance using a four-step scale. To find out the absolute relevance of the forms of interaction, the 'relevance index', that is the shares of responses with the assessment 'important' or 'very important', was generated. This is presented in Table 1. Collaborative research and informal contacts were found to be the most important types of interaction between industry and universities in this study. (Meyer-Krahmer & Schmoch, 1998, 840)

Table 1. Ranking of types of interaction between universities and industrial firms from the perspective of academic researchers (Reprinted from Meyer-Krahmer & Schmoch, 1998, 840)

Rank	Interaction type	Relevance index
1	collaborative research	74
2	informal contacts	71
3	education of personnel	60
	doctoral theses	60
	contract research	56
	conferences	56
	consultancy	52
4	seminars for industry	39
	scientist exchange	39
	publications	35
5	committees	31

In the same article Meyer-Krahmer and Schmoch (1998, 841) reported on a survey related to university advantages of interactions with industry in Germany, presented in Table 2. In the survey the most important advantage to a university was the additional funding, and the second advantage was knowledge exchange. The relevance index of both advantages was nearly the same.

Table 2. Ranking of advantages of interactions between universities and industrial firms from the perspective of academic researchers (Reprinted from Meyer-Krahmer & Schmoch, 1998, 841)

Rank	**Advantage**	**Relevance index**
1	additional funds	87
2	knowledge exchange	84
3	flexibility of industrial funds	75
4	additional facilities	61
5	references for public projects	52

The university professors were also asked what they perceived as the interest of industry in collaboration between industry and universities. Most professors assumed that for industry the main interest in collaboration was the observation of scientific development (Meyer-Krahmer & Schmoch, 1998, 842), as seen in Table 3.

Table 3. Ranking of industrial interests in interaction with universities from the perspective of academic researchers (Reprinted from Meyer-Krahmer & Schmoch, 1998, 842)

Rank	**Assumed interest of industry**	**Relevance index**
1	observation of scientific development	82
2	solution of technical problems	70
3	recruitment of personnel	69

The last survey addressed the importance of disadvantages of, or barriers to, interaction with industry, seen in Table 4. The major problem was found to be the short-term orientation of industrial partners. The second most common problem was limited industrial basis. This may be due to different research cultures in industrial companies and universities. Restriction of publications was ranked the third position among the restrictions. It was found that compared to the advantages, the disadvantages were less critical. (Meyer-Krahmer & Schmoch, 1998, 842)

Table 4. Ranking of disadvantages of interaction between universities and industrial firms from the perspective of academic researchers (Reprinted from Meyer-Krahmer & Schmoch, 1998, 842)

Rank	Disadvantage/barrier	Relevance index
1	short-term orientation	68
2	limited industrial basis	42
3	restriction to publications	38
4	less interesting topics	35
5	administrative problems	25
6	unfair terms of contract	18

The recruitment of graduates was not found to be of the highest importance, but scientific development and additional funds were important from the academic researchers' point of view. Meyer-Krahmer and Schmoch (1998, 848) concluded that at German universities of all the fields examined, the central linking element in co-operation between universities and companies was the bi-directional exchange of knowledge.

Santaro's and Chakrabarti's four important I/U relationship alternatives

Four industry-university relationship alternatives were analysed by Santoro and Chakrabarti (2002). The data was obtained from 12 National Science Foundation program evaluations and survey protocols and 15 semi-structured interviews with industrial company representatives and university center directors in the United States (Santoro & Chakrabarti, 2002, 1164-1169). The focus of the study was on university research centers working together with companies, because the centers encourage collaboration with industry. The university research centers have an explicit mission to transfer knowledge with industrial companies. According to the study, industry benefits of interactions include possibilities to recruit highly trained students, facilities, and faculty, and the prestige of collaborating with a recognized academic institution. Universities can benefit by getting additional funding for research. Universities can also benefit from collaboration by getting additional opportunity to familiarize their faculty and students with practical problems, gain employment possibilities for their graduates and access to applied technological areas. (Santoro & Chakrabarti, 2002, 1164)

Large companies seem to have more intense knowledge transfer and research support interactions, but on the other hand less intense cooperative research and technology transfer, for strengthening skills, for knowledge and for arranging access to university facilities for non-core technologies. However, small companies with fewer financial resources have more intense technology transfer and cooperative research interactions, and less intense knowledge transfer and research support interactions, for strengthening skills, for knowledge and for arranging access to university facilities for core technologies. (Santoro & Chakrabarti, 2002, 1166-1167)

In research support, according to Santoro and Chakrabarti (2002), industry supplies funds or equipment as an interaction to a university. Research support was the least interactive form of interactions analyzed in the study. Companies may focus their support on projects that are beneficial to the company, for example gaining new information for a company. (Santoro & Chakrabarti, 2002, 1164) Cooperative research, consultancy by faculty and individual investigations was the second relationship alternative. Individual investigations and consulting can mean a faculty member working on a project of a company. Group arrangement is one form of cooperative research and can mean industry staff working through industry advisory boards and with university research centre faculty. (Santoro & Chakrabarti, 2002, 1164-1165) Knowledge transfer was the third alternative proposed presented by Santoro and Chakrabarti (2002). It includes formal and informal personal interactions, cooperative education, curriculum development and personnel exchange. In this alternative recruitment of graduates and employing students are the main forms of knowledge transfer between industry and academia. Knowledge transfer can take place in cooperative education designed to encourage information exchange and industrial placements for undergraduate and graduate students. Cooperative education programs help universities to provide state-of-the-art technology courses and make it possible for graduates to meet the needs of industry in terms of knowledge. (Santoro & Chakrabarti, 2002, 1165) Technology transfer was the fourth proposed relationship alternative between industry and university. The focus in technology transfer is on more specific industry issues by driving research with industry expertise and then producing applications for the market and the transfer can take place via technological consultancy arrangements and via jointly owned ventures. (Santoro & Chakrabarti, 2002, 1165)

To summarize, the four models of interactions presented above focus on collaboration on the country-specific level. Two analyses, Meyer-Krahmer's and Schmoch's, (1998) and Geiger's (2004) present funding as an important element of collaboration between industry and higher education. However, the types and commonness of interactions vary depending on the discipline, and thus the findings of these models are not directly comparable with one another, but provide background for further comparison and discussion. The models of interactions proposed by Meyer-Krahmer and Schmoch (1998) and D'Este and Patel (2007) show that researchers interact with industry through various channels. D'Este and Patel (2007) conclude that there is still little consensus in the literature about patterns of interactions between industry and higher education among university researchers (D'Este & Patel, 2007, 1309). On the other hand the study by Santoro and Chakrabarti (2002, 1164) relates to relationship alternatives focusing on university research centers.

2.2.2 International-Level Interactions

While several studies have been carried out on country-specific forms of interactions, only few studies were found on interactions on the international level. Two studies (Okubo & Sjöberg, 2000; Leydesdorff & Wagner, 2008) on international-level interactions investigated international collaboration through the production of academic publications, which can be considered one form of international collaboration between industry and higher education. However, the studies did not investigate other forms of interactions, nor did they have an industry viewpoint. Also, the data used in the studies was relatively old. In a more recent study (Marginson, 2010), the growing role of higher education and research in the worldwide economy was examined.

The changing pattern of industrial research collaboration in Sweden, particularly the extent to which industries participate in academic research, was studied by Okubo and Sjöberg (2000) using a bibliometric approach. The approach is used to measure the scientific performance of a country or institution by their production of scientific publications (Okubo & Sjöberg 2000, 84). The main data was extracted from the CD-ROM of the Science Citation Index database produced by the Institute for Information Science in Philadelphia, USA, from 1986 and 1994. The findings of the study by Okubo and Sjöberg, in relation to the present study, included that of international publications in engineering and technology in Sweden almost one fourth were produced with company participation. Furthermore, Swedish and international researchers in cooperation produced more than half of industrial scientific publications in Sweden. Another finding was that company participation in research increased the speed of the development of internationalization of universities compared to a situation where research was conducted by universities and other research institutions alone. Also Swedish companies were increasingly inclined to collaborate with research groups outside the country and foreign companies were collaborating increasingly with Swedish public research institutions.

The study further highlighted some important issues. In order to advance research, scientists worked in groups linking together heterogeneous research institutions in various countries. Interesting details were that a merging of competencies was more evident among companies than among universities and that private companies were increasingly integrating with national and international academic networks. Cooperation and networking seemed to be becoming ideal forms of scientific production for companies. (Okubo & Sjöberg, 2000, 85-96) However, it should be noted that although the article was published in 2000, the findings were based on data from 1986 and 1994.

International collaboration in science and the formation of a core group was studied by Leydesdorff and Wagner (2008) who measured international collaboration by co-authorship relations on refereed papers. The data was retrieved from the CD-ROM database of the Science Citation Index for articles, reviews, letters and notes for 1990, 2000 and 2005. The findings showed that the co-authorship of papers increased linearly in terms of the number of papers, but increased exponentially in terms of international addresses. In the study it was also proposed that international collaboration could be regarded as a communications network which is different from national systems. Specifically, Leydesdorff and Wagner (2008, 317) stated this as follows:

> We suggest that international collaboration in science can be considered as a communications network that is different from national systems and has its own internal dynamics. National systems have policies and institutions that mediate scientific communication, while at the global level the network exists mainly as a self-organizing system.

The study showed that the network of international collaborations in science has expanded quickly after 2000. The network has become denser, meaning in general that countries participating in collaboration have supported and increased the number of collaborators on the global level. (Leydesdorff & Wagner, 2008, 320-321) However, the study only concerns papers produced in international collaboration in science, not in industry, nor does it provide information about other forms of interactions in collaboration. On the other hand, the study provides interesting knowledge about co-authorship of papers published in international collaboration. Furthermore, the study highlights the difference between the network of international collaboration in science and national systems.

Higher education in the global knowledge economy was studied by Marginson (2010), focusing particularly on the changing global landscape of higher education where both higher education and knowledge are simultaneously global, national and local. The study was based on recent research for policy papers prepared for OECD on globalization and higher education as well as the internationalization of higher education in Asia-Pacific, on case studies of leading universities in eight Asia-Pacific nations, and on comparative data from the OECD, UNESCO and the World Bank. The major findings of the study, in relation to this study, included the following. The nature of research and the distribution of research capacity were the most important elements determining the nature of the world-wide environment in higher education and the potential of individual nations. However, the rise of new science powers, for example in Asia, may change the situation, and the knowledge economy power and patterns of language usage may change. Also, education and research in one country can affect those in others. The cross-border effects can be positive, such as global flows of people, ideas, knowledge, messages, technologies and capital, or negative, such as emigration of educated people, ‘brain drain’. Furthermore, most of interactions between nations in higher education do not seem to take the form of trade but the form of free exchange and cooperation, which means the production of global public goods. (Marginson, 2010, 6962-6978)

The study provides significant views of future developments in the increasing role of higher education and research in the knowledge economy on the global scale. However, the study does not include discussion of the forms of international interactions involved in worldwide knowledge economy, nor does the study provide insight into industry-university collaboration.

To sum up section 2.2, some studies have been carried out on topics related to international collaboration but they do not include information about international interaction forms nor do they provide an industry perspective. On the other hand, various studies exist on industry-university interactions on the country-specific level, including interaction forms, but they do not provide an international perspective. The present study aims to fill this gap by examining international industry-university interaction forms by using primary data collected from existing global collaboration programs in IT. In addition comparative data retrieved from previous country-specific studies, presented in section, is used as secondary data.

2.3 Analytical Framework for Global Collaboration Networks

This section includes a presentation of the theories forming the framework of this study. This study is at the interfaces of social sciences and technology in that it is a social sciences study, but the topic is studied through case studies from the field of technology.

2.3.1 Overview

With regard to the analytical framework, this study draws primarily on the following models in the description of international collaboration and related interactions: Castells's (1996) concept of network (discussed in detail in Section 2.3.2) and Gibbons's et al.(1994) Mode 2 model (discussed in detail in Section 2.3.3). Some complementary theoretical aspects related to collaboration are also discussed to enhance the understanding of collaboration and interactions.

The concept of network developed by Castells (1996, 470 - 471) is discussed first. Some other approaches related to networks are also considered to complement the view of the studies on networks. Gibbons et al. (1994, 167) have created a model they call Knowledge Production in Mode 2. The present study draws on the Mode 2 model to consider how new knowledge is generated in a heterogeneous collaboration system between industry and higher education and what the role of communication intensity is in knowledge production. According to Gibbons et al. (1994, 167) Mode 2 is used in the context of an application, which makes the model applicable in this study focusing on collaboration in application development. Mode 2 exists alongside the traditional Mode 1 Knowledge Production system, which is scientifically focused (Gibbons et al., 1994, 14-15). Mode 1 Knowledge Production is identical with what is meant by science, it is characterized by homogeneity and it is hierarchical (Gibbons et al., 1994, 3), and therefore it is not a part of the framework of this study.

2.3.2 Networks as Social Organizations

The social theory of space and the theory of the space of flows have been described by Castells (1996). Space is the expression of society and society is constructed around flows: flows of capital, flows of information, flows of technology, flows of organizational interaction, flows of images, sounds and symbols. The space of flows is based on communication networks and communication network links, together with places with social, cultural, physical and functional characteristics. Places can be exchangers, communication hubs coordinating the interactions of elements in a network.

Other places are the nodes representing the location-based activities around the key functions of the network. Networks define nodes depending on the functions and hierarchy of each node and depending on the product or service processed in the network. In the theory of space and flow, the assumption is that societies are asymmetrically organized around the specific social interests of each social structure. (Castells, 1996, 410 - 415)

A network set-up may be physical or logical. An interconnection set-up is also considered a part of network architecture, the design and implementation of a communication network with respect to its communication disciplines and its interconnection set-up. According to Castells (1996), networks are open structures and thus can expand and integrate new nodes as long as they share the same goals. Networks are good structures for an economy based on innovation, globalization and decentralized concentration. (Castells, 1996, 470–471) The nodes may have a varying relevance depending on the time of the network, and the nodes can increase their importance for the network by processing and generating information more efficiently. Also the relative importance of a node depends on its ability to contribute to the goal of the total network. (Castells, 2004, 3)

There is no center in a network-form society, just a set of interconnected nodes. Redundant and useless nodes are reconfigured or deleted by the network. (Castells, 2004, 3) A collaborative network and Research and Development (R&D) are also ways to increase the creation of new innovations. The free sharing of knowledge is an important mechanism to create new innovations and further development based on the information received (Castells, 2004, 40). A network is an efficient social organization for various reasons. First, it is flexible and can reconfigure according to the changing environment and requirements, keeping its goal. Second, it is scalable: it can change its size when necessary and go to places with good resources. Third, it can almost always survive; there is no center and it can operate in a wide range of configurations and even have many dimensions and form a network system. (Castells, 2004, 5-6) Furthermore, a company may consist of local offices and research and development units located in several countries, and industry may also go after skilled labor, especially for research and product development. Large companies can be said to be internally decentralized as networks (Castells, 2004, 28).

A network as a social organization has been studied by Castells (1996, 470-471), and a set of interconnected nodes and free sharing of knowledge were found to be an important mechanism to create innovations (Castells, 2004, 40). Therefore, his concept of network is applicable to this industry-university collaboration study. Regarding networks, this study draws mainly on Castells's concept of network, but some other approaches related to networks are also considered in the following to complement the view of network-form collaboration.

Networks have features similar to other types of organizations, such as a set of mutual interests and goals, a basis for membership, an agreed means, and sometimes style, of communication, a sense of a collective goal, a degree of specialization, a means of co-ordinating and directing activities (Ottewill, Riddy& Fill, 2005, 139). In application development and collaboration there may be a mutual interest and goal, a style of communication specific to a field of science and there may also be co-ordination. This type of organization in industrial companies is often called a project organization and it can be geographically distributed to different places. In this study a collaboration network is considered to be such a system. At a basic level networks are simply collections of people who stay in touch, who pass around data, tools, ideas, and encouragement. One important purpose of a network is to remind its members that they are not alone. (Ottewill, Riddy& Fill, 2005, 139) Especially in collaboration networks the data, tools and ideas are shared between participants of collaboration to achieve a common goal.

Networking can have many forms and dimensions. The coalitions, alliances and networks are built through many processes and they may remain highly informal and to a degree invisible. Different networks may have common points. Coalition building may, for example, occur over the telephone, through old-boy networks and other friendship groups, through the golf club and former colleagues. (Morgan, 1997, 186) In the context of the present study, the increase in the size of the collaboration network can be assumed to increase the amount of *the total communication* and knowledge of the network-related topic researched, because every node has its amount of knowledge relating to the fields of applied sciences and has its resources, and every node engages in communication with other nodes using different links.

An efficient state can be called a network state, as argued by Carnoy (2001). “It is a state made of shared institutions, and enacted by bargaining and interactive iteration all along the chain of decision making” (Carnoy, 2001, 31). The new state operates as a network in which nodes interact and are equally important for the functions of the state. The efficiency of the state is defined in terms of its capacity to create and sustain networks. (Carnoy, 2001, 31) In addition, different linkages can be specified in terms of flows of knowledge and information, flows of investment funding, flows of authority and informal arrangements such as networks, clubs, and partnerships. There may be strong and weak, regular and irregular, intense or relaxed kinds of interactions shaping the system. (Cooke, Uranga & Etxebarria, 1997, 478)

It should be noted that different forms of interactions and collaboration between industry and higher education can take place in a network consisting of several companies, higher education institutions and other developers forming a collaborating system taking the form of a network.

Effects of globalization on collaboration networks

Globalization can be understood as a positive phenomenon, offering industry and people new possibilities. Competition has increasingly changed from local to global. Furthermore globalization can be considered the compression and intensification of understanding on a global scale (Väyrynen, 1998, 65). It polarizes societies and leads to wider international co-operation and integration. However, it may also discriminate against people without the knowledge, skills and education needed on the market (Väyrynen, 1998, 57-58). A global network may also have an immaterial form, as for example knowledge and funds, which move very easily and may locate to any place and even many places at the same time (Normann, 2002, 74).

The first important dimension of globalization is the global economy. Castells (2001a) stated that the heart of the global economy is the global financial market. Other important dimensions of globalization are the transformation of international trade and the internationalization of production. A dimension, which is also close to the viewpoint of this research, is the globalization of science and technology. More specifically, it means the selective globalization of science and technology. There is a concentration of science and technology and especially information technology, research and development in the leading countries. Instead of diffusing, information technology has concentrated the research and development capacity. A key characteristic of the global economy is that it is organized in networks. The networks are within large companies and they are decentralized networks. (Castells, 2001a, 2-11)

Furthermore, globalization makes the borders of states easier to cross (Drucker, 2000, 80). Therefore for stopping international funds to a country's territory and to stay competitive, countries have to invest more in education to increase the productivity of the workforce (Väyrynen, 1998, 157). The role of the global economy is nowadays more important than formerly in the development of local economies, employment, education, salary levels, and social politics. If countries cannot satisfy the international companies, the companies will have as an alternative to move their production and development to a more attractive country (Väyrynen, 1998, 196).

Markets have become global and thus the market forces should also be taken into consideration. Companies go closer to the market with production and product development. This is to make localization more precise, minimize transportation and keep stock values at a lower level. The origination of products becomes domestic, and production transfer expedites the launch of products. Technologies are controlled by big international companies which have the best productivity in countries in which the level of education is high and there is sufficient experience of using that specific technology, and in which adaptability to new technologies is fast (Väyrynen, 1998, 133). New technologies yield added value only when a company has a critical mass of personnel capable of innovations and creative thinking. The personnel must also be able to work in teams, because it is in teams that new technologies can be used and new products developed most efficiently (Väyrynen, 1998, 133).

However, the development depends on technology, and the industrial nations have a lot of technology, unlike the developing countries. Thus the difference between the developed and developing countries may increase as a result of globalization, because technology is increasingly privatized and made available to those who can pay and educate for it (Turner & Hulme, 1977, 32). In increasing global competition a nation's ability to fund research may become very important. Developed countries often fund research, especially technologies and research that are important to the country's industry and competitiveness. However, the developing countries' capacity to fund technologies and research may be limited.

In addition the motives to establish R&D units in different countries are driven by learning from technological excellence, markets and dynamic interactions between R&D, marketing and manufacturing. For example the European Union can attract students by its ability to support learning processes in complex system innovations and the interactions of firms, R&D institutes, universities and policy administration. (Meyer-Krahmer & Reger, 1999, 773)

In a worldwide setting higher education can be seen in three dimensions: the global, the national, and the local, as suggested by Marginson (2010). Higher education and knowledge have simultaneously three dimensions. Marginson (2010) specifies global to refer to spaces, systems, relations, elements, and identities constituting and constituted by the world as a whole or by large parts of the world in pan-national regions such as Europe. Globalization includes global flows in communications, transport and financial systems, cross-border mobility of people, and elements such as language and research exchange that integrate nations and individuals across borders. However, while international relations across borders may involve only two nations, globalization involves many nations. Globalization is a dynamic process which is difficult to predict, drawing the local, national and global dimensions closer together. (Marginson, 2010, 6963 - 6964) In addition, research universities, as Marginson (2010) notes, are included in the key nodes and drivers in globalization and are often primary agents in opening up their nations to global collaboration. The major research universities are intensively linked in global networks that comprise the nodes of a networked world. There seems to be a strong positive correlation between the higher education enrolment ratio of a nation or a region and its global competitive performance. (Marginson, 2010, 6964)

On the other hand the continuous change of courses can become a trap for education, and institutions which are committed to continuous improvement cannot recognize that the rules of the game, such as new technologies, are improving faster than the institutions themselves and that the game has totally changed (Normann, 2002, 111). This may mean that an institution must have effective methods to scan its environment to obtain correct, fresh and reliable information for decision making. To succeed, educational institutions, like industrial companies, should be members of several networks to stay in the flow of reliable information and to be able to collaborate with other institutions and industry. As Drucker (2000) states, all institutions must set global competitiveness as their goal. No university can stay alive and further succeed if it does not meet the norms and quality set by the leading institutions in its field of science on a global scale. (Drucker, 2000, 78) Furthermore, if investment in education and research cannot meet the training needs of the labor market, they are not effective and high education cannot produce the expected effects regarding improvements in productivity, economic growth and development (Castagna, Colantonio, Furia & Mattoscio, 2010, 3749).

The concept of network is an important part in the framework of this study to describe global collaboration and interactions which take place in a heterogeneous network. The information which diffuses in the network forms bidirectional information flows between nodes and is used in collaboration for various purposes, such as production of knowledge and further applications. In the following, the Mode 2 model, which is another part of the framework of the study, is described. The model has been developed for description of knowledge production and in this study is used to describe application development in the different nodes of a collaboration network.

2.3.3 Knowledge Production and Application Development in Collaboration Networks

Mode 2 is carried out in the context of an application and marked by various factors: transdisciplinarity, heterogeneity, organizational heterarchy and transience, social accountability and reflexivity, and quality control results from the parallel expansion of knowledge producers and users in society. (Gibbons et al., 1994, 3). Transdisciplinarity takes place only if research is based on a common theoretical understanding. A transdisciplinar mode consists of continuous linking and relinking and clustering. The transdisciplinary mode is a temporary configuration and thus highly mutable. (Gibbons et al.,1994, 29) Mode 1 problems are solved in a context governed by the interests of a specific group, while Mode 2 knowledge is processed in the context of an application.
Mode 1 is a disciplinary and homogeneous system, while Mode 2 is a transdisciplinary and heterogeneous system. (Gibbons et al., 1994, 3)

The Mode 2 (Gibbons et al., 1994, 167) model is used in this study to describe the generation of application-related knowledge such as applications and publications in collaboration programs. Mode 2 is applicable here, because the model operates in a very heterogeneous environment and focuses on application development rather than on academic research. The difference between application development and academic research is not always clear, but the focus in applications means using existing technologies and the focus in science means the production of new scientific knowledge to be used in applications. Another reason for using Mode 2 in this study is its focus on the increase of communication, communication intensity which is applicable to network-form co-development.

Mode 2 (Gibbons et al. 167) is thus heterogeneous in terms of the skills and experience of those participating. Communication between the Mode 2 system nodes takes place via social, electrical and organizational links which may form a global web. Mode 2 is socially distributed and many nodes participate in communication (Gibbons et al., 1994, 68). The increasing international competition between companies makes Mode 2 type of knowledge production necessary for industry and may create new challenges for governments. (Gibbons et al.,1994, 14-15)

Possible applications of the model

Because of the transdisciplinary nature of Mode 2, the disciplinary boundaries and distinctions between pure and applied research and institutional differences between universities and industry have less meaning. The focus of all of these is on the problem area. (Gibbons et al., 1994, 30) The success criteria of Mode 2 (Gibbons et al. 1994, 33) are the applicability, efficiency or usefulness of the developed transdiciplinary or solution. It may be difficult to maintain a balance between collaboration and competition, because sophisticated technical solutions are needed and companies must be more closely involved in knowledge production. Therefore companies may, for cost and standardization reasons, engage in joint research and application development, even if they are competitors in business.

There are also some potential problems in the application of the model. A problem of Mode 2 (Gibbons et al., 1994, 167) may be management. The focus of collaborative projects may be lost and the results may not be controllable and identified in detail. Furthermore, socially distributed knowledge production may take the form of a global web, which may be difficult to manage (Gibbons et al., 1994, 122). A knowledge production system may consist of several institutions and entities, such as universities and industrial companies. Their modes of operation and specialized knowledge related to the collaborating fields of science may differ widely, which may make management difficult. Another potential problem is cultural differences. In Mode 2 knowledge is produced in a variety of organizations and institutions, including multinational companies, network companies, small hi-tech companies in specific technology, government institutions, research universities, laboratories, likewise institutes and national and international programs (Gibbons et al., 1994, 6). A third problem may be that in a multicultural environment funding also comes from various sources and the range of requirements and expectations may be different and enter the context of the application (Gibbons et al., 1994, 6-7).

The heterogeneous growth in Knowledge Production in Mode 2 is referred to as the process of differentiation and diffusion through which the rearrangement of component elements takes place in a given process. The process of heterogeneous growth is called the increasing density of communication. It can be divided into three communication levels: between science and society, among scientists, and with the entities of the physical and social world. On these three levels and in the links between participants, communication density has greatly increased. (Gibbons et al., 1994, 18) Communication is an important factor in Mode 2 (Gibbons et al., 1994) knowledge production and the density of communication is a key variable. An increase in the density of communication is an indication that the rate of diffusion is increasing. (Gibbons et al., 1994, 35)

Expanding collaboration between industrial companies and higher education institutions in application development and research in multi-site international projects can be compared to the theories proposed by Gibbons et al. (1994, 35) relating to the diffusion and density of communication. The expanding collaboration network of networks can be said to diffuse because of the increasing number of links, universities and companies. The links between universities and companies may carry different amounts of knowledge, but when the collaboration network of networks diffuses, the total amount of information carried by the links increases, and the total amount of communication increases in a case where the new sites of a network are active in communication.

Examples of viewpoints of industry and universities in collaboration networks

The perspective of this study is the industry perspective but also the university perspective is important in industry-university collaboration networks. Universities are key players in various networks and may have country-specific level and international-level roles in collaboration networks. Examples of viewpoints of both industry and universities in collaboration are briefly described below to enhance the understanding of the functions of collaboration networks and to provide a more profound understanding of the environment of the study.

The following examples illustrate some functions of industry and universities in collaboration networks. Universities should focus their functions on research and education since industry has traditionally seen collaboration with universities primarily as a source of employees and secondarily as a source of knowledge useful to the company. From this point of view industry wants basic research knowledge from universities. (Etzkowitz, 1998, 824 - 825; see also Reddy, 1997, 1832).

Furthermore, knowledge and information flows through social networks are more numerous especially between entities in a network than across the borders of a network. For example informal contacts inside a company are more frequent than informal contacts between a company and a university. Furthermore, knowledge is more frequently received from engineers of other companies than through contacts between university and industry. On the other hand engineers of companies participate in informal projects with university and engineers who are educated at the local university are more likely to receive knowledge from university researchers via informal contacts. (Östergaard, 2009, 196)

Between university and companies knowledge can also flow through the mobility of graduates in addition to formal cooperation and informal social networks. In a study by Östergaard (2009, 196-199) some interaction forms in collaboration between university and companies are listed. They include formal research projects (joint research or contract research), mobility of scientists, training, consultancy and education of graduates, informal contacts between employees of companies and university researchers. Also in the field of education, colleagues, graduates, and fellow students may form a network. Interpersonal networks in particular are considered an important channel for the diffusion of different knowledge and information (Cantner & Graf, 2006, 464). In addition, if companies and the university can develop a good way to exchange information**,** they would know which skills are available for further collaboration.

Finally, issues related to funding in collaboration networks have also been studied. There might be opportunism among companies and universities in collaboration. Companies may contact the university only to be able to apply for some program funds, but when the incentive is over, the relationship with the university is also over. The university may also establish relationships with companies to obtain available funds even if they are not prepared to solve the problems that need to be solved. (Sutz, 2000, 288) Furthermore, industry funding and university professors' research performance was studied by Gulbrandsen and Smeby (2005). They found that research at universities is increasingly funded by industry and the share of basic funding is decreasing. It was also found that commercialization in terms of industrial funding is significantly related to university professors' research activity. On the other hand, commercialization in terms of entrepreneurial output is not significantly related to academic performance. (Gulbrandsen & Smeby, 2005, 932) The commercialization of research moreover raises considerations related to the protection of research findings. Mowery (1998) stated as early as 1998 that universities should put more effort into seeking to protect and license the results of publicly and privately funded research. (Mowery, 1998, 652)

The examples below illustrate some functions of universities and industry related to knowledge production. The more heterogeneous the knowledge production coalition network is, the more theoretical or practical the institutions are, and the more views can be covered to reach the common goal and innovations. Universities have remained at the center of knowledge production by using collaboration mechanisms. (Godin & Gingras, 2000, 277) The growth rates of different countries were studied by Lundvall, Johnson, Andersen and Dalum (2002). One of the explanations for the different growth rates were differences in the research systems of various countries. It seemed that most of the new knowledge did not come directly from higher education and technical research and in many industries not even from research and experimental development, but rather from other sources such as production engineers, customers, or marketing. Nation-states had their own agendas for innovation. (Lundvall, Johnson, Andersen & Dalum, 2002, 215) Interactions between science and industry are an important aspect of the innovation ecology, because it contributes to the diversity of knowledge that is an important feature of the sustainability of systems (Caraca, Lundvall & Mendonca, 2009, 866; see also e.g. Ståhle & Ainamo, 2012; Johnson, 1992, 39).

Finally, some success factors and barriers in collaboration between industry and universities have been examined. Collaboration was found to be successful because of shared goals, planning, mutual trust and effective communication (Mead, Beckman, Lawrence, O'Mary, Parish, Unpingco & Walker, 1999, 161). Barriers in collaboration included primarily cultural and attitudinal issues (Davies, 1996, 4). Furthermore, university-industry interactions are heterogeneous and there is a diversity of outcomes. The heterogeneity of interactions should be allowed to flourish. However, there are too few channels for interactions, too few disciplinary and sectoral patterns of interactions and commercialization and too few types of universities and companies (Gulbrandsen, Mowery & Feldman, 2011, 1).

As appears from the examples discussed above, the functions of universities and industry in networks are multidimensional because the environments and set-ups of networks vary.

The analytical framework of the present study

The analytical framework of the present study consists of the concept of network (Castells, 1996) and the Mode 2 model of knowledge production (Gibbons et al.,1994). In the following the framework is illustrated with additional elements to enhance the understanding of the collaboration and interactions and information flows between them.

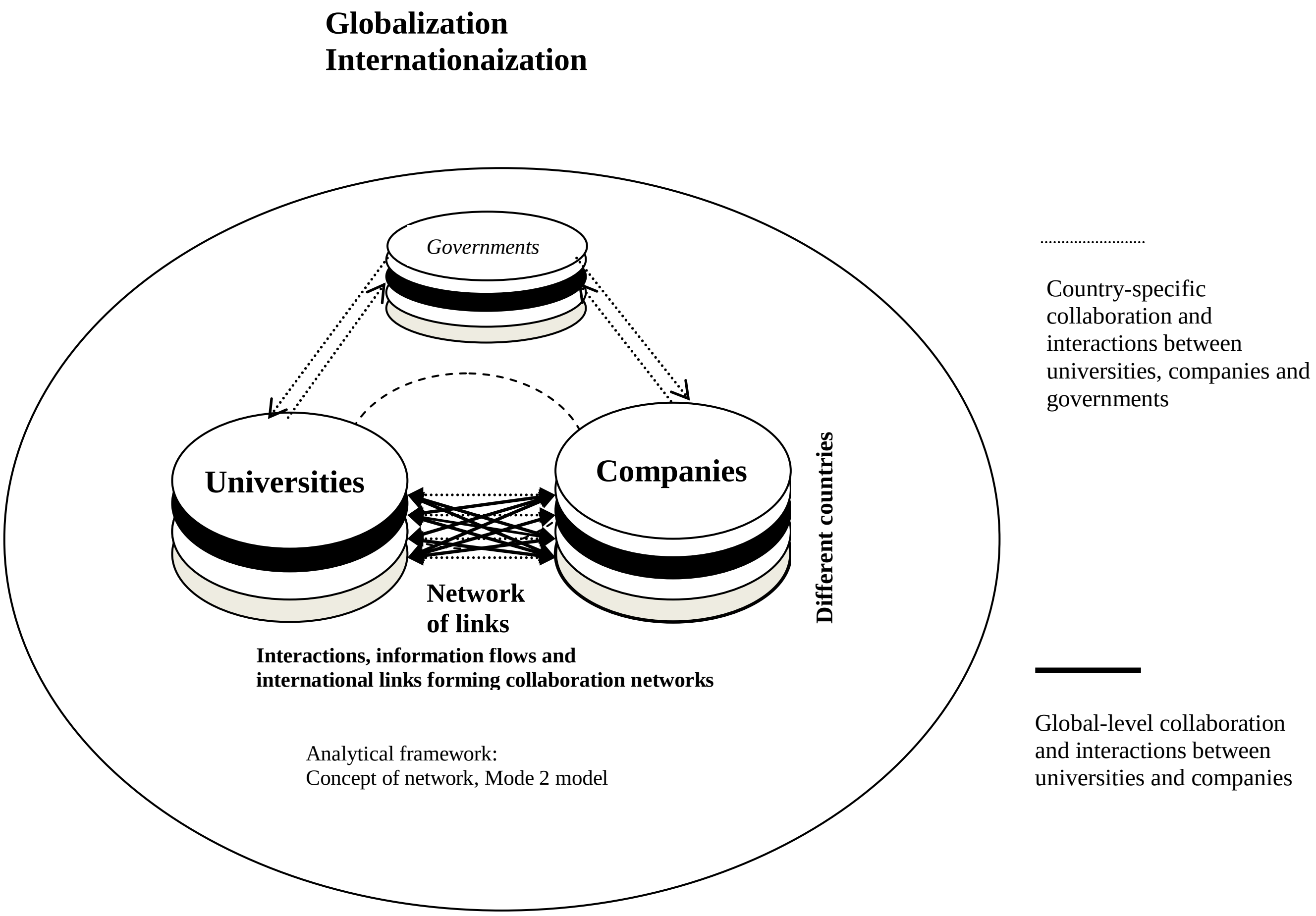


Figure 2. Analytical framework

In most countries government has some influence on collaboration between industry and higher education on the country-specific level. Country-specific level collaboration between industry and higher education and also government influence on collaboration are presented in Figure 2 by horizontal dotted arrows. Different countries are described in Figure 2 by different layers. International information flows and interactions are described in the framework in Figure 2 by thick crossing arrows, between universities and companies in different countries. The influence of governments on international collaboration between industry and higher education is small, if any. Global collaboration networks and related international forms of interaction occur and can be seen in Figure 2 when universities or/and industrial companies in different countries interact and information flows form international links between them over the borders, as shown by thick crossing arrows. Forms of country-specific collaboration are described here by the inner level circle with a thin broken line, and internationalization, forming global collaboration networks, is described by the outer circle.

An important element in this study framework is the inclusion of the global dimension which was not found in the frameworks of previous studies describing industry-university collaboration. The focus of this study is on global collaboration networks and the international interaction forms used in them. This study examines the set-ups of global collaboration networks consisting of links and nodes and related interaction forms as well as activities included in them. In this study the concept of network is used to describe a global collaboration network consisting of links and nodes, that is, educational institutions and industrial companies and linkages between them. Mode 2 is used to describe activities related to knowledge production in heterogeneous collaboration networks. A collaboration network is considered to be a heterogeneous system, because all educational institutions and industrial companies are different.

3 METHODS AND MATERIALS

In this study I examine the different forms of international interactions between the information technology industry and engineering education in the context of global collaboration. In the following the research design as well as case selection, data collection and analysis method are described.

3.1 Research Setting

3.1.1 Research Design

The research design of this study consists of a literature review of past studies (presented in Section 2.2), which form the secondary data of this study, and a case study design for the study of the primary data of the present study, consisting of document data and interview data. The purpose of including previous studies in this study as secondary data is to provide a reference level against the development of forms of interactions, especially when moving from country-specific towards international collaboration. On the other hand, a case study design is one approach to qualitative research (see e.g. Creswell, 1998, 62) and according to Miles and Huberman (1994, 25) the case is a phenomenon of some sort occurring in a bounded context. A case study can be used as a method when the researcher has little control over events and the phenomenon studied is in the context of real life (Yin, 2009, 2). In this study the collaboration programs of the four companies analyzed are existing programs. Furthermore, a multiple case study as a research method allows the researcher in this study to retain the holistic characteristics of real-time events, such as international relations (see e.g. Yin, 2009, 4).

The study explores collaboration through multiple cases and the data was collected from multiple sources. As for the primary data of this study, 6 global collaboration programs of 4 case companies, all major global IT companies, were examined. In addition, interviews with 10 respondents were carried out, 6 of whom were from industry, 3 from universities and 1 from a UAS.

The rationale for using multiple sources of evidence is called data triangulation (Yin, 2009, 114). Data triangulation provides an opportunity to use several different sources of evidence, which makes it a strong approach to case study data collection (Yin, 2009, 114 - 115; 2002, 97 - 98). Possible problems of construct validity can be taken care of with data triangulation, because multiple sources of evidence provide multiple measures for the same phenomenon. Case studies using multiple sources of evidence are rated more highly from the overall quality point of view compared to single source studies. (Yin, 2009, 116-117) Another way to increase construct validity is the chain of evidence approach to data collection (Yin, 2009, 42). According to Yin (2009) external validity relates to the problem of whether the findings of a study are generalizable by defining the domain. Reliability of the case study relates to repeating the same case study and arriving at the same findings and conclusions. (Yin, 2009, 43-45) However, the purpose of this study is not to generalize the findings but rather to enhance the understanding of industry-university collaboration and its development in international environments.

Some considerations should be taken into account related to both secondary and primary data. Considering the use of secondary data, it must be noted that it can only produce evidence that is firmly rooted in the contexts in which the original studies have been carried out. For example, all the studies included in the literature review had a technical viewpoint but they had been carried out in various specific contexts and in different countries. All studies include also a human aspect. The findings and conclusions have been interpreted by authors of the original articles and in this study the review and analysis of secondary data is further interpreted. (See e.g. Randolph, 2007) Also the use of primary data includes some considerations. The time difference between this study and the possible repeated study relates to possible generated errors, because new forms of international interactions are continuously introduced. Repeating the case studies and arriving at the same findings and conclusions is also critical depending on the time elapsing between the studies, because of developments in global collaboration between higher education and the IT industry. (See e.g. Yin, 2009) However, the interviewees would not respond identically in the same way in a repeated study.

3.1.2 Case Selection and Data Collection

Case Selection

In screening the "candidate" cases of a multiple case study the cases which best fit the replication design should be selected (Yin, 2009, 91). The search was carried out through a World Wide Web search, using the search terms, university, collaboration, and program. As cases for analysis in this study 6 global collaboration programs representing 4 global IT companies were selected. The following selection criteria were used: at the time of data collection, the global collaboration programmes were programs of global IT companies which operated and had active collaboration also in Finland, and a sufficient amount of data of the collaboration programs was provided by the companies. A part of the data of some collaboration programmes or even a whole collaboration program might be company-sensitive information without open access. A company collaborating with universities in various countries and thus forming an international network with universities is a relatively new phenomenon. Therefore at the time of data collection for this study, no more collaboration programs filling the selection criteria explained above were found.

Data Collection

Today data can be obtained from two main types of sources, online and offline (Markham and Baym, 2009, 34). In this study documents of global collaboration programs and emails for an interview can be considered to be online data.

The primary data consists of the following types of data:

1) program data obtained from the documents of 6 global collaboration programs of 4 case companies

   and

2) structured questionnaires sent to 11 respondent candidates from 4 IT companies, 4 universities and one UAS, all of them actively involved in tasks related to collaboration between industry and higher education. The

respondent candidates of the IT companies were personnel from the human resources department or personnel working or having worked in collaboration programs with higher education. The respondents of the universities were mainly professors. All in all, 10 respondents replied to the questionnaire, 6 respondents from companies, 3 respondents from universities and one respondent from a UAS.

Also secondary data was used in this study as comparative data (the literature review presented in Section 2.2).

Program Data

The program data for this analysis was collected from the documents of the selected companies claiming to have established global collaboration with higher education. The program data was thematically analyzed to identify the main forms of international interactions.

Such collaboration programs are a relatively new phenomenon and the programs operate in an electrical working environment. Thus documents and tools related to collaboration are also available in electrical form. However, the names of the global collaboration programs and related companies and the interviewees of the related companies are not disclosed in this study to respect the anonymity of the programs, companies and interviewees. The respondents do not officially represent their companies or universities in the interview. Similarly, the focus of the study is not the companies, but forms of international interaction and thus the names of the programs are not mentioned. Furthermore, the program data collected for this study was open access data published by the companies within the scope of their choice. Any possible further data would be company-sensitive in nature and not available for study. Also it is important to note that the opinions of the respondents and the program documents may have changed since data collection, and also for these reasons it is irrelevant to mention the names of the companies and the interviewees. “Anonymity serves to protect the real case and its real participants” (Yin, 2009, 181). The anonymity issue is taken care of at two levels: the entire cases and the individuals within the cases (Yin, 2009, 181). To combine the program data and the structured interviews, the companies analyzed are given case numbers. The same numbers are used in both descriptions and analyses.

Structured Interview

One possible source of case study data is the interview (Yin, 2009, 106). In the present study, based on the nature of the research problem and questions, the data collection for the second analysis took place in the form of an interview. An interview on global collaboration between industry and higher education was conducted as a part of the study to see how the picture the companies give of the collaboration program documents of their international forms of interactions, outcomes and operation with higher education support the picture generated from the responses to the interview.

In a qualitative study using structured interviews the interviewee can be seen as a research 'subject' in a similar way to completing a questionnaire or taking part in an experiment. The researcher's concern is to obtain accurate information from the interviewee without the effect of relationship factors. However, the qualitative researcher believes that there cannot be a 'relationship-free' interview. (King, 2004, 11)

Email was selected as the medium for the interview. The responses given by email were in text form and thus directly documentable. The questionnaire was sent to 6 persons in IT companies and to 5 persons in higher education acting in collaboration between industry and higher education. In total 6 responses were received from industry and 4 responses from engineering education. All in all the respondents came from four countries Finland, China, the Netherlands and the United Kingdom. Some of the global companies interviewed have an organization with specific personnel for international collaboration with higher education institutions but not all. These factors placed the respondents in slightly different positions.

The interview questionnaire consisted of 10 open-ended questions. They were developed on the basis of the findings of the previous country-specific studies analyzed and summarized in Table 5 in Section 3.2**.** In the interview questions the focus was on interaction forms in global collaboration networks between the information technology industry and engineering education.

The questionnaire consisted of the following questions (also see Appendices 3 and 4):

1) What are the three main forms of international interactions your company is doing with higher education?
2) What are the reasons for the collaboration of your company with higher education? Give three reasons.
3) Is application development and production included in your collaboration with international higher education? If yes, what kind of applications have been developed and produced?
4) What is the importance of collaboration with international higher education from the possible recruitment point of view?
5) What is the importance of collaboration with international higher education from the knowledge transfer point of view?
6) How does your company fund the collaboration with international higher education?
7) What kind of student projects do you have?
8) Is training of students in the form of industrial placement or summer job a part of your collaboration with higher education? If yes, what type of training do you offer?
9) Does your company participate in advisory boards (neuvottelukunta) at universities of applied sciences? If yes, what is your role in the board?
10) Are publications an outcome of collaboration with higher education? If yes, what type of publications have been produced?

For higher education the questions were:

1) What are the three main forms of international interactions your institution is doing with industry?
2) What are the reasons for the collaboration of your institution with international industry? Give three reasons.

3) Is application development and application production included in your collaboration with international industry? If yes, what kind of applications have been developed and produced?
4) What is the importance of collaboration with international industry from the possible recruitment point of view?
5) What is the importance of collaboration with international industry from the knowledge transfer (in either direction) point of view?
6) How does your institution receive funds from international industry for the collaboration?
7) What kind of student projects do you have with international industry?
8) Is training of students in the form of industrial placement or summer job a part of your collaboration with international industry? If yes, what type of training?
9) Does your institution participate in advisory boards (neuvottelukunta) at universities of applied sciences? If yes, what is your role in the board?
10) Are publications an outcome of collaboration with international industry? If yes, what type of publications have been produced?

In the following, the empirical analysis procedure is described. First, the collaboration programs are presented and the different forms of interactions are thematically analyzed to find out the main forms of interactions. Second, the interview responses are themed and the analysis results are compared to those from the program data analysis. Third, the results of previous studies on country-specific forms of interactions (presented in section 2.2.1) are theme analysed for reference. The analysis results are then compared to the results of the program data analysis and the interview data analysis.

3.1.3 Data Analysis Method

The data was analyzed by thematic analysis. It is a method for identifying, analyzing and reporting different patterns and themes within data (Braun & Clarke, 2006, 79; also see Boyatzis, 1998, p.4-5). For this study thematic analysis was selected as the method because of the nature of the data which is in textual form, and to support comparisons between the results of different analyses.

A critical issue in thematic analysis relating to credibility is to select the most suitable unit of meaning. Too broad meaning units may be difficult to manage, because they contain various meanings. One aspect for interpretation is that a text always involves multiple meanings and the researcher's interpretation is influenced by his or her personal history. (Graneheim, Lundman, 2004, 107, 110, 111)

In the analysis process I first studied and familiarized myself with the data. Secondly theme units of analysis were generated by comparing different data relating and not relating to each other. Next the selected theme units were reviewed. Finally the theme units were named to represent the forms of interactions analyzed. In the following the secondary data is theme analyzed to provide a reference level for comparison with primary data. After that the primary data is theme analyzed. The same theme units were used in all the analyses.

3.1.4 The Researcher's Position

Qualitative research is interpretative research and a researcher should analyze his or her values and experience of the topic in the research report (Creswell, 1994, 147) for a possible bias. Mezirow (1991, 42) chose a term 'meaning perspective' to indicate "the structure of assumptions within which one's past experience assimilates and transforms new experience. A meaning perspective is a habitual set of expectations that constitutes an orienting frame of reference that we use in projecting our symbolic models and that serves as a (usually tacit) belief system for interpreting and evaluating the meaning of experience." Meaning perspectives are structures which are mostly "prerational, unarticulated presuppositions", leading to distorted views of reality. (Mezirow, 1991, 42, 62) The selection of the research topic and understanding of the final results of the research always relate directly to our lives (Varto, 1992, 16).

My work experience in various positions in international information technology industry and engineering education has contributed to my understanding of the topic of the present study. However, although I have previously worked in one of the companies hosting the studied programs, none of the interviewees were my former colleagues. During almost ten years in engineering education I have collaborated with the IT industry on the country-specific level and with some companies and universities on the international level. In this study the data describing the phenomenon studied is collected from multiple sources, and thus it zero-sets the generated bias in the results of the analyses. Using multiple sources of evidence is data triangulation (Yin 2009,114). In addition to the primary data collected for this study, also secondary data retrieved from previous studies is used as comparative data.

3.2 Analysis of Literature Review Material

In this section the secondary data gathered from previous studies related to forms of country-specific forms of interactions, including models of interaction, are theme analyzed as comparative data for reference to see possible similarities and differences when compared to the results of the theme analyzed primary data, that is, collaboration program data (Section 3.3) and interview data (Section 3.4). The secondary data was presented in Section 2.2.1.

As can be seen in Table 5, the variety of country-specific forms of interactions is large within knowledge transfer, which appeared to be the most common form of interactions on the basis of the studied secondary data. Consulting as a form of knowledge transfer was a result in the majority of the articles and was also included in all the four models of country-specific forms of interactions. Also research and development appeared to be a common form of interaction on the basis of secondary data and it was included in three of the four models of interactions. Furthermore, licensing was given as a form of interaction in several articles, but in none of the models of country-specific interactions. The same was the finding related to research centers. As can be seen in Table 5 most country-specific forms of interactions, on the basis of the secondary data, were related to knowledge transfer. As two further main forms of interactions emerging from the secondary data seemed to be recruiting and funding.

Table 5 provides a summary of the secondary data after theme analysis.

Table 5. Country-specific forms of interactions found in the secondary data

Forms of Interactions		Models for Forms of Interactions			
Knowledge transfer	**References**	Patel & D'Este (2007, 1301)	Geiger (2004, 195-196)	Meyer,Krahmer & Schmoch (1998, 840)	Santoro & Chakrabarti (2002, 1164-1165)
Research and Development, Research	Lee & Win, 2004; Siegel, Waldman, Atwater & Link, 2003; Lee, 1996; Schartinger, Rammer, Fischer & Fröhlich, 2002; Arvanitis, Kubli & Woerter, 2008	Joint Research	Field-intensive knowledge	Collaborative research	
Licensing	Lee & Win, 2004; Shane, 2002; Siegel, Waldman, Atwater & Link, 2003; Baba, Shichijo & Sedita, 2009; Philpott, Dooley, O'Reilly & Lupton, 2010; Siegel, Waldman, Atwater & Link, 2004				
Contract research	Lee & Win, 2004; Boardman & Ponomariov, 2009; Hoye & Pries, 2009; Bekker & Freitas, 2008; Philpott, Dooley, O'Reilly & Lupton, 2010	Contract Research		Contract research	
Sponsored research	Shane, 2002; Westhead & Storey, 1995				Research support
Consulting	Shane, 2002; Nikulainen & Palmberg, 2010; Lee & Win, 2004; Hoye & Pries, 2009; Philpott, Dooley, O'Reilly & Lupton, 2010; Westhead & Storey, 1995; Baba, Shichijo & Sedita, 2009; Arvanitis, Kubli & Woerter, 2008	Consulting	Field - extensive knowledge	Consultancy	Cooperative research
Collaboration R&D	Nikulainen & Palmberg, 2010; Bekker & Freitas, 2008; Decter, Bennet & Leseure, 2007; Heinze & Kuhlman, 2008; Behrens & Gray, 2001				
Technology transfer	Siegel, Waldman & Link, 2003			Scientist exchange	
Technology transfer program	Trune & Goslin, 1998		Instrumenta tion		Technology transfer
Exchange program, student projects	Lee & Win, 2004; Mead, Bekman, Lawrence, O'Mary, Parish, Unpingo & Walker, 1999; Westhead & Storey, 1995; Lee, 1996				
Joint venture	Lee & Win, 2004; Siegel, Waldman, Atwater & Link, 2003				
Science park, spin-offs	Lee & Win, 2004; Philpott, Dooley, O'Reilly & Lupton, 2010; Arvanitis, Kubli, & Woerter, 2008	Creation of Physical facilities			
Training	Lee & Win, 2004; Mead, Bekman, Lawrence, O'Mary, Parish, Unpingo & Walker, 1999; Philpott, Dooley, O'Reilly & Lupton, 2010; Westhead & Storey, 1995; Schartinger, Rammer, Fischer & Fröhlich, 2002	Training			
Research centre	Boardman & Ponomariov, 2009; Nikulainen & Palmberg, 2010; Santoro & Gopalakrishnan, 2000				
Conferences, seminars, lectures, courses	Nikulainen & Palmberg, 2010; Arvanitis, Kubli & Woerter, 2008; Lee & Win, 2004; Hoye & Pries, 2009; Carrington, Strooper, Newby & Stevenson, 2005	Meetings, Conferences		Conferences, Seminars for industry	
Public R&D projects	Nikulainen & Palmberg, 2010				
Publications, theses	Nikulainen & Palmberg, 2010; Lee & Win, 2004; Philpott, Dooley, O'Reilly & Lupton, 2010; Baba, Shichijo & Sedita, 2009; Schartinger, Rammer, Fischer & Fröhlich, 2002			Publications, Doctoral theses	
Informal informational activities	Arvanitis, Kubli & Woerter, 2008; Lee & Win, 2004; Hoye & Pries, 2009; Westhead & Storey, 1995			Informal contacts	Knowledge transfer
Sabbaticals	Hoye & Pries, 2009				
Committees	Hoye & Pries, 2009			Committees	
Recruitment	Heinze & Kuhlman, 2008; Westhead & Storey, 1995		Personnel enhanceme nt	Education of personnel	
Funding	Westhead & Storey, 1995				

In Table 5 the themed forms of interactions, based on the secondary data, are presented in the left-hand side column. The middle column provides the articles constituting the theme analyzed secondary data. The right-hand side columns provide the main forms of interactions of the four studied models themed parallel with other secondary data.

3.3 Global Collaboration Programs: Program Data and Analysis

In the following, the primary data consisting of collaboration programs is presented and then theme analyzed. First some central concepts are clarified. Collaboration programs typically focus on development of different types of applications. In the following the concept of application is briefly defined. Referring to social sciences Gibbons et al. (1994) state that the context of an application is problem solving, and the generation of knowledge organized around a particular application is not only applied research or development. It includes the interests, institutions and practices which might negatively influence the problem to be solved (Gibbons et al., 1994, 167). Foray and Gibbons (1996, 274) state that knowledge produced in the context of an application is always produced under an aspect of continuous negotiation and will not be produced before the interests of the various actors are included. In the IT the concept of application is used for example to refer to new ways of using electronic components and software. In this study application refers to a new way of using electronic components to provide a platform for software and a piece of software providing new services in information technology. To bridge the gap in the knowledge about international interactions between the global collaboration programs of the IT industry and engineering education, the present study was conducted from an industry perspective.

Different forms of interactions from the viewpoint of the analytical framework of this study refer to different events taking place in heterogeneous collaboration networks between different nodes, such as universities and global IT companies, to gain new applications and knowledge. In the following, the global collaboration programs are first presented. Secondly, the various forms of interactions are analyzed, and thirdly conclusions are drawn from the findings.

3.3.1 Case Program Descriptions

The global collaboration programs were analyzed to form a view of international forms of interactions between the IT industry and engineering education and to provide a new view of international forms of interactions between them. The participants in the collaboration included in the case program descriptions are companies in the global IT industry, universities and some UASs. The universities and UASs participating in collaboration mainly represent engineering education. In all the programs described the collaboration networks consist of one company in the international IT industry and several universities. The companies of the case programs, representing the IT industry in this study, are global mobile phone companies, network equipment suppliers, and companies researching, developing and producing electronic devices and components.

The global programs analyzed are established programs operating globally and funded by the IT industry. The collaboration programs presented are managed mainly by the IT industry, and engineering education also has a role in management in suggesting new topics for collaboration in some programs.

The students participating in collaboration programs are mainly undergraduate and graduate engineering students, in some programs also postgraduates. Through the programs the students familiarize themselves with real-life technical problems and the latest technologies used by the IT industry. Students also obtain new information and experience of the technologies used by the IT industry.

The amount of available data used as the primary data of this study differs depending on the collaboration program studied, because the mode of operation differs depending on the program. Also the programs represent different developmental stages of collaboration but still they represent the current state of global collaboration. However, it should be noted that the purpose of the study is not to compare the different programs but to find and analyze different forms of international forms of interactions in various existing programs.

Case 1 Programs

The purpose of the collaboration program, program 1a, is to arrange international groups of students to research and develop innovative ideas and probable solutions to technical problems together with experts on information technologies. The goals of the collaboration program are to establish innovative and creative teams to conduct high-quality research related to telecommunications and information technology, but not necessarily to develop technical solutions. Student groups in the program are supervised by academic and industrial experts. The groups of students are divided into research teams, and each team has its own problem to solve related to information technology or telecommunications technology. Industrial and academic experts may set a new research problem, and also a student team may propose its own research problem. The tasks should be creative, project-based training problems and should help students to scale the risks, so that there will be opportunities to achieve concrete results. However, the results of the projects are not only deliverables, but additionally the "competence incubation" environment and good teams capable of carrying out research and design work independently. It is recommended that a publication in a reputable journal or conference be published as an outcome of each project. The students and supervisors participating in the program come mostly from Finland, Russia, Germany, and Sweden. The program is aimed to increase intellectual and cultural interaction between industry and higher education institutions.

There are two membership categories in the program: university and industrial membership. Some of the university members are full members and some observers. The full member universities have the right to be present at the steering committee and must provide at least one expert for the advisory board. The observer status universities can attend open seminars and have representatives on the advisory board. Regarding the industrial members, the host company is currently the only industrial co-founder and key contributor in the program, but other companies can also join the program as industrial members. New industrial members can join the program after being approved by all current industrial members. Member companies have the right to be present at the steering committee and must also provide at least one expert for the advisory board. As a program co-founder the host company has the priority vote compared to other industrial members in the event of a conflict of interest.

A new team must first formulate a research proposal and make a research plan. Then the research proposal and plan is delivered to a local program coordinator for formal review. If the proposal is satisfactory, the local program coordinator forwards the proposal to the advisory board members. The local coordinator acts as a facilitator of communication between the program advisory board and the team proposing the research problem. After commenting on the project proposal and finding a project supervisor, the local coordinator delivers the project proposal to the steering committee for decision. For universities the program provides a means of internationalization and to get contracts with new research and project partners. For students the program provides guidance by academic and industrial experts in their field of professional interest. The program provides financial support for students when a paper written by them is accepted for presentation at a conference recommended by the program advisory board.

The steering committee is the highest authority in the program and takes care of strategic management and general supervision. Normally the steering committee is charged with the administrative function only, such as calling program meetings and organizing new research groups. In the steering committee there are industrial and full university members. Representatives have one vote each. Other members may be invited onto the steering committee, but they do not have the right to vote. The advisory board includes representatives from industry and business, the public sector and universities related to information technology. The advisory board produces expert feedback on the students' research plans, papers and research topics. The industry and academic members of the advisory board may change depending on the situation and need for specialists. Each full-member university is assigned a local coordinator. The local coordinator monitors the progress of the projects of the university, negotiates about change requests related to the projects with the advisory board and the steering committee, and collects review and financial support requests from the local teams.

Each project on the program has a project supervisor, who is in charge of the project. The only limiting factors of a research team are defined in the project scope and timescale agreed with the steering committee. If a student wants to join a project team, he/she contacts the project supervisor to discuss the research topic and the formalities of participation. A student or group of students may make a proposal to form a research team following the program rules and format. The new team may suggest a new research topic or may be given a research topic by the advisory board. At least one member of the advisory board must support the proposed new research topic. The supporting advisory board member will then become the project supervisor. If the topic is given by the advisory board or is selected from a set of open topics, the topic originator becomes the supervisor of the project team or alternatively some other competent supervisor is appointed project team supervisor. This is the only collaboration program of the case programs describing the management and related organization.

The goal of program 1b is to provide an opportunity for universities and the host company to share information and ideas on the local culture. The universities participating in design projects come from different parts of the world. This collaboration program is not only focused on mobile devices or recruiting new talents, but on presenting local influences which may turn out to be global trends. In the first phase in the program students explore sources of inspiration and key influences of their country's culture. In the second phase students create local scenarios and products using the information gained during the visual research projects.

Program 1c is a special developers' forum for developers of different types of applications for host company products. The program is a community providing tools and support for developers in different countries and companies. The developers' forum for universities is a part of the program targeted at higher education. The developers' forum for universities is a program between the host company and universities providing support and information for faculty and students developing applications on product platforms of the host company. The program provides eLearning materials, documentation, online materials, software development kits and examples of programs.

New books and teaching materials about software systems are also available. Program c for universities organizes developer events in different countries and innovation competitions. There are also forum innovation seminars highlighting the practical applications of innovations.

Case 2 Program

In the global trainee program the host company invests in talent. There are four topics of the program related to global training: finance and business control, human resources and sustainability, information systems, and marketing and sales. A person applying to join a program should be a recent university graduate with above-average grades, for example, in computing, IT, information systems or related majors, at MSc level or equivalent. The applicant should have a mature, professional personality with realistic goals and good communication skills. The applicant should also be fluent in English, be a flexible team player and have a global mindset, and social and intercultural competence.

The learning scope on the global trainee program for information systems depends on the interests and personal preferences of the trainee. The main focus of all trainee programs is on-the-job experience customized to each trainee's development needs. As a minimum a trainee should gain insight into the following areas in the case of the global trainee program and information service delivery infrastructure and application operation, security, risk management and technology planning. In the case of information systems architecture the insight should be focused on corporate roadmap, integrating systems, standards setting. In information systems sourcing insight should be gained into vendor management, contract negotiations and license management. In personal development the focus is on the global trainee program and information systems related to corporate missions and values, international and virtual teamwork, leadership and management skills, presentation, communication and motivation skills, innovation and creativity and social competence.

The global trainee program for information systems lasts between 18 and 24 months and includes three assignments. The first assignment is accomplished in the country of origin or current place of residence. In the first assignment a trainee gains experience in one or more areas according to his/her learning scope, for example, infrastructure operations, security or technology planning. The first assignment takes six months. The second assignment takes place at regional headquarters or host company headquarters. The second assignment a trainee may select from options such as supporting information systems architecture or information systems architecture in a global trainee program for information systems. This assignment should give an insight into strategic information systems. The final assignment is an international one. The trainee is actively involved in the organization with particular responsibilities and/or destinations. This assignment may last up to 12 months and is a challenging project assignment.

The trainee is assigned a mentor for the program and a tutor or supervisor for each individual assignment. In addition to learning on the job, trainees can attend series of personal training events, factory tours, and social and cross-functional activities. Mentors let trainees benefit from their experience and help to see issues from a different angle. They help trainees to plan the trainee program and assist in setting up contacts for trainee's future careers. Mentors are experienced professionals in their fields and in the programs selected by trainees. In addition to mentors trainees are assigned personal tutors for the supervision of individual assignments.

Case 3 Program

Case 3 program focuses on application development and involves host company collaboration with universities around the world. The purpose is to give university students the opportunity to learn new technologies in the host company. The purpose of collaboration is also that students gain hands-on experience and learn about new trends in the communications industry.

In practice the program includes collaboration with universities by IP Multimedia Subsystem (IMS) activities such as lectures and seminars on architecture and application development or business ideas. IP stands for Internet Protocol, the basic protocol used to allow the Internet to exchange data with the network attached to the

Internet. The lecturers are from the host company or from partners. Within the program the host company also arranges contests and developer events and provides for example software tools. Collaboration creates business opportunities for university applications and supports collaboration with operators and the media companies. One objective of collaboration is the development of IMS competence for the global and local markets which will further inspire and promote IMS application development. The second objective of collaboration is to build IMS knowledge and to secure innovative IMS applications to be brought to the market. The third objective is that by introducing technology innovation and practical business cases in an academic environment, the host company together with students will develop applications for potential new services.

Case 4 Program

Case 4 program develops university partnerships and further programs, provides financial resources, offers expertise and donates equipment globally. One of the goals is to attract high-ability graduates. Another goal is to collaborate with universities to educate engineers needed by the host company and its suppliers and customers in the future. Through the university program students use the technologies of the host company internationally in laboratories and make innovations. In addition the program offers scholarships and assists in developing curricula and degree programs with universities. The host company is also a founding member of the Engineering and Technical Consortium collaboration among industry, the United States Federal and State governments and universities to increase the number of graduates in engineering and computer science from some universities to meet market demands. The program engages universities internationally to teach engineers to do design with products of the host company and to research critical technological breakthroughs for industry.

The program involves different forms of interactions with higher education. For example, the host company funds laboratories and facilities for universities. Investments have taken the form of host company products for design work, laboratory equipment and funds to build or upgrade engineering facilities. Other forms of interactions the host company uses include participation in technical advisory boards and university research reviews.

The purpose of the worldwide university program of the host company seems to be knowledge transfer and it provides support internationally for educators, researchers, and students internationally in matters concerning the integration of technology of the host company through courses, design and research projects. The members of the university program can get discounts on equipment, technical training, teaching materials, books, technical support and local program support.

3.3.2 Analysis of Case Program Data

The forms of interaction analyzed in this section relate to the analytical framework of the present study. The basis for collaboration networks is drawn upon the theory of networks as social organizations (Castells, 1996) because the different international forms of collaboration analyzed take place in networks, such as the global collaboration programs presented in this section. Knowledge production and application development in collaboration networks are modeled with Mode 2 (Gibbons et al.1994, 167). The programs analyzed can be considered to be collaboration programs, because the random rewiring probability of a network is low, the network is highly cliquish and its path length is short (Kim & Park, 2009, 8987). This means that access to the network is not free and communication between the network participants is efficient. The network made by a small probability is called a ‘small-world’ network (Kim & Park (2009, 8987).

Table 6 summarizes the types of international forms of interactions gathered from the program data of this study and then analyzed by thematic analysis.

Table 6. International forms of interactions between industry and higher education found in the primary data

Knowledge transfer	Case Programs
Student projects	Case 1a, 1b, 1c Case 3
Technology transfer	Case 1a, 1b, 1c Case 3 Case 4
Publications	Case 1a, 1b, 1c
Regional academic forums	Case 4
Thesis writing	Case 3
Training	Case 3
Recruitment	Case 1a, 1b, 1c Case 2 Case 3 Case 4
Funding	Case 1a, 1b, 1c Case 4

Thematic analysis was used as a method to analyze the textual data collected. First the program data collected from the documents was studied. Secondly the theme units of analysis were generated from the data. Next the selected theme units were reviewed. Finally the theme units were named to represent the forms of interactions, as summarized in Table 6. In comparison with Table 5 presenting country-specific forms of interactions found in the secondary data, it can be concluded that the same main themes, that is the main forms of interactions, were identified in the secondary data (Table 5) and the primary data (Table 6). The most notable difference was that the number of different interaction forms related to knowledge transfer was considerable higher in country-specific collaboration than in global collaboration. Examples of interaction forms which were present only in the country-specific secondary data were science parks, research centres, and joint ventures. On the other hand, interaction forms which were found in both the primary and secondary data included technology transfer, publications and training, in the category of knowledge transfer. Furthermore, in both sets of data recruitment and funding were mentioned as forms of interactions.

Further analysis of the program data

Some programs served well both industrial and educational goals. Case programs 1 a, b, and c were examples of ways of collaborating globally between industry and higher education as a multi-participant system, resembling a network structure because of multiple nodes. The request to produce a report on each project in Case 1a program made the participating students evaluate the implementation and success of the project. Appendix 1 provides examples of publications produced in collaboration programs.

Collaboration between institutions representing different countries familiarized students with international and global collaboration and also the working environment. Such a research and development model made it possible to use supervisors from industry and higher education in parallel with research and development projects. Case 1a program was also one way for students to familiarize themselves with the industrial host company by participating in the program. Furthermore, for industrial companies participation in programs such as Case 1a program was a way to recruit high-ability students and in some cases harvest new innovations, because the program was managed and the operation was controlled. In Case 1b program students formed a design community which, besides designing mobile devices and finding new talents, had a goal to collect information about local cultures. In Case 1c program, the application development program provided support and information for universities and students. The information was for developing new applications on the platforms of the host company. The collaboration programs operate as a network where there is one company from the global IT industry and several universities, which is modelled in this study by networks as social organizations (see e.g. Castells, 1996, 470).

Marketing the products of the host company could also be a reason behind knowledge transfer. Case 4 program aimed to attract high-ability students globally. The purpose was to educate engineers, to use the components of the host company for development of the applications of different client companies, and to create innovations in the laboratories of Case 4 program host company. The aim was that the components of Case 4 host company would be used in application development in the clients' laboratories.

The places to produce new applications could vary globally, and thus it was not possible to collect data of the client companies of Case 4 program host company as was done in Case 1. The program data also indicated that in global collaboration and application development programs different types of events were organized, such as seminars, competitions and conferences, where information and experiences relating to the technology developed could be exchanged between developers. Knowledge was transferred and tools were delivered mainly over the Internet, using home pages and webinars, that is, seminars over the web.

On the basis of the program data it seems that collaboration between the IT industry and higher education often focuses on application development and harvesting of new applications rather than on science and the development of new knowledge. The complex, heterogeneous and often freely expanding network structure brings an increase in the number of communication links between nodes formed of engineering education institutions and companies. The diffusion of an application development network increases the development power, because more people are involved in development, and the total amount of knowledge related to the collaboration fields of technology of the network thus increases. The set-ups of developers' forums and programs are often free and global, and any institution which desires can participate. There are many types of developers' programs. However, in this study the focus is on global collaboration programs intended for collaboration mainly in application development between the IT industry and engineering education.

The applications and possible innovations may also be produced outside the programs using the tools of the program, such as software development kits. In well-managed application development programs the outcomes are measurable in contrast to totally freely expanding and unmanaged programs, where the systematic compiling of statistics does not or cannot take place. Application development programs offer higher education institutions and students an opportunity to familiarize themselves with the latest technologies via design projects. For students the programs offer, besides a chance to learn about the latest technologies, a chance to know the companies and their technologies better for possible employment and to tune the study plan to better match the future career. Working in projects close to industry often increases the students' motivation, since they can see that the knowledge acquired can be used. This also gives them a chance to learn skills to work in international projects. For society application development collaboration programs between industry and higher education can give a better match between engineering education and the knowledge needed in working life.

3.4 Global Collaboration: Interview Data and Analysis

As a part of the case study design, interviews by using questionnaires sent by email were conducted to study the forms of international interactions between the global IT industry and higher education, and to see whether the interview results support the results obtained from the program data (Section 3.3**).** Interviews with 10 respondents were carried out, 6 of whom were from industry, 3 from universities and 1 from a UAS. The interview questionnaires were sent to employees, all involved in collaboration, of the same case study companies as those from which the program data was collected, and the same numbers as for cases are used here for reference. Furthermore, employees, mainly professors, of four different higher education institutions were interviewed using the same set of questions. After that the data gathered from the interviews was theme analyzed.

Analysis of Interview Responses

In the following, the responses of the industry respondents are analysed first. Table 7 summarizes the responses of the respondents related to three main forms of international interactions between industry and higher education, which was question 1 in the questionnaire. As in the results obtained from the data gathered from the documents of the global collaboration programs, in the interview various forms of knowledge transfer and recruitment were seen as the main forms of international interactions between industry and higher education. The results from the two sources of data support each other well when Table 6 (Section 3.3.2) and Table 7 below are compared. Numbers in this section and the case numbers in Sections 3.3.1 and 3.3.2 refer to the same company.

Table 7. Three main forms of international interactions between companies and higher education according to industry respondents

Company, Country	Form of Interaction 1	Form of Interaction 2	Form of Interaction 3
Company 1, CH	Research collaboration	Knowledge transfer	Recruitment and interns
Company 1, FIN	Physical facilities	Contract research	Knowledge transfer
Company 1, FIN	Technology exploration, Projects, Knowledge transfer	Professional communities	New courses in relevant technologies
Company 4, UK	Enrichment of courses	Recruitment	New innovations
Company 3*, FIN	Fairs, excursions	Knowledge transfer	Interns and theses
Company 2**, FIN	No international interactions	No international interactions	No international interactions

Table 7 presents the main forms of international interactions in order of importance according to the respondents' preferences. The company respondents 2** and 3* answered only on behalf of the company in Finland. CH= China, UK= United Kingdom, FIN= Finland

As seen in Table 7, all the companies considered knowledge transfer or recruitment the main forms of international interactions.

Next the responses of the higher education respondents to question 1 are analysed. Table 8 below shows the responses received from higher education institutions. Knowledge transfer is stated to be the main form of international interaction between the IT industry and higher education, mainly in different forms of projects.

Table 8. Three main forms of international interactions between companies and higher education according to higher education respondents

Institution, Country	Form 1 of Interaction	Form 2 of Interaction	Form 3 of Interaction
University 1, CH	Technical projects	Research and publications	Funding
University 2, FIN	Research projects	Technical projects	Researcher exchange
University 3, FIN	Theses	Technical projects	Student projects
UAS*, NL	Student projects	Knowledge transfer	-

*UAS = University of Applied Sciences, NL= Netherlands

In Table 8 forms of interactions are presented in order of importance according to the preference of the respondents.

Question 2 was about the reasons for international collaboration between industry and higher education. The reasons given in the majority of the responses related to recruitment and knowledge transfer, as can be seen in Table 9. This partly explains why industry respondents consider international interactions with higher education necessary.

Table 9. Industry reasons for international collaboration with higher education

Company, Country	Reason 1 for Collaboration	Reason 2 for Collaboration	Reason 3 for Collaboration
Company 1, CH	Creating ecosystems	Recruitment	Innovations
Company 1, FIN	Knowledge transfer	Applications	Innovations
Company 1, FIN	Social responsibility	New innovations	Knowledge transfer
Company 4, UK	Marketing, long term	Recruitment	Innovations
Company 2*, FIN	Visibility, Employer branding	Knowledge transfer	Recruitment
Company 3**, FIN	Recruitment	Marketing, Employer branding	Social responsibility

Table 9 presents the reasons in order of importance according to the preference of the respondents. Company respondents 2* and 3** answered only on behalf of the company in Finland.

As Table 9 shows, the main reasons for international interactions are knowledge transfer and recruitment. An interesting detail in the responses was social responsibility which was given as a reason for collaboration in two of the responses.

Responses from higher education institutions to question 2, Table 10, show that in higher education knowledge transfer is also the most important reason for interaction with the global IT industry, but recruitment and funding are also given as reasons.

Table 10. Higher education reasons for international collaboration with industry

Institution, Country	Reason 1 for Collaboration	Reason 2 for Collaboration	Reason 3 for Collaboration
University 1, CH	Student projects	Knowledge transfer	Recruitment
University 2, FIN	Funding	Knowledge transfer	Improve research relevance
University 3, FIN	Recruitment	Funding	Creating ecosystems
UAS*, NL	Knowledge transfer	Internships	-

*UAS = University of Applied Sciences

Table 10 presents the reasons in order of importance according to the respondents' preference.

From the perspective of this study, question 3 relating to application development is important. In all the responses given by industry, application development was included in the forms of interactions with higher education. Application development is further included in knowledge transfer. Applications can be developed and produced for new ideas and innovation harvesting purposes. Table 11 shows the industry responses relating to application development.

Table 11. Application development included in collaboration with higher education

Company, Country	Is application development included in interactions	What type of applications are developed	Second type of application developed
Company 1, CH	Yes	Prototypes	Applications
Company 1, FIN	Yes	Prototypes	Test production
Company 1, FIN	Yes, as a side product	Applications	Services
Company 4, UK	Yes	-	-
Company 2*, FIN	No	-	-
Company 3**, FIN	Yes	-	-

In Table 11 company respondents 2* and 3** answered only on behalf of the company in Finland.

Responses from higher education institutions to question 3 can be seen in Table 12. As can be seen half of the respondents included application development in international interactions. However, the respondents did not specify the types of applications in their responses.

Table 12. Application development included in collaboration with industry

Institution, Country	Is application development included in interactions?	What type of applications are developed?
University 1, CH	Yes	Applications
University 2, FIN	No	Applications
University 3, FIN	Yes	Applications
UAS*, NL	No	-

*UAS = University of Applied Sciences

Because recruitment is an important form of interactions for industry, question 4 was about the importance of collaboration for recruitment. For several reasons, all the companies, as can be seen in Table 13, considered collaboration important from a recruitment perspective, for slightly different reasons.

Table 13. Importance of collaboration with higher education from the recruitment perspective

Company, Country	**Reason 1 for Collaboration, Recruitment perspective**	**Reason 2 for Collaboration, Recruitment perspective**
Company 1, CH	Fostering competence	Long term growth and loyalty
Company 1, FIN	Early stage screening	-
Company 1, FIN	Important aspect	-
Company 4, UK	Cultivation of the best people	Recruitment
Company 2*, FIN	Securing the best possible competence	Attracting the best candidates already during studies
Company 3**, FIN	No, only local recruitment	-

In Table 13 the reasons are presented in order of importance according to respondents'. Company respondents 2* and 3** answered only on behalf of the company in Finland.

An interesting point in the results, Table 13, was that many responses mentioned the best people, the best candidates, and early stage screening in connection with recruitment. This may mean that the search for future high-ability employees starts during collaboration between industry and higher education.

The representatives of higher education institutions interviewed indicated in their responses to question 4 that recruitment is one important reason for collaboration, as can be seen in Table 14.

Table 14. Importance of collaboration with industry from the recruitment perspective

Institution, Country	**Reason for Collaboration Recruitment perspective**	**Reason for Collaboration Recruitment perspective**
University 1, CH	Attracting students	-
University 2, FIN	Industry searching for talents	Creating collaboration
University 3, FIN	Attracting students	-
UAS*, NL	Recruitment	-

*UAS = University of Applied Sciences

Table 14 presents the reasons in order of importance according to the preference of the respondents.

Question 5 concerned the importance of knowledge transfer in collaboration. The respondents considered knowledge transfer an important form of interaction and collaboration for several reasons. The responses showed that knowledge transfer was found to be an important form of international interactions. An interesting detail was that building an ecosystem was mentioned in one response. This might mean a collaboration network with several links. The other reasons for knowledge transfer included: targeted training of specialists, scouting and transfer of new ideas and knowledge, and collaboration with the academia. However, in the responses of higher education to question 5, knowledge transfer was prominent among the reasons for collaboration with the IT industry. It was also stated in one response that collaboration with a company transferred practical experience to higher education.

Funding was the topic of question 6 in the interview. It appeared that internationally interacting companies used some way of funding for collaboration. Table 15 shows the different ways of funding reported by company respondents.

Table 15. Ways of funding collaboration from the industry perspective

Company, Country	**Way 1 of Funding**	**Way 2 of Funding**
Company 1, CH	Long term relation	-
Company 1, FIN	Collaborative research centers	Direct research ordered from educational organizations
Company 1, FIN	Corporate level funding	Joint partnering programs
Company 4, UK	Grants	Support from marketing for long term business development
Company 2*, FIN	Separate yearly budget	-
Company 3**, FIN	-	-

In Table 15 the ways of funding are not presented in order of importance. Company respondents 2* and 3** answered only on behalf of the company in Finland.

It also appeared that funding could be directed to projects with an interest in a funding company. Such cases are partnering programs, company funding for research proposals and collaborative research centers. As shown in Table 15, funding can also mean support for long-term business development.

In their responses to question 6, the majority of higher education respondents considered funding to be part of international collaboration, as can be seen in Table 16. The European Union was mentioned in one response as a source of funding.

Table 16. Ways of funding collaboration from the higher education perspective

Institution, Country	**Way 1 of Funding**	**Way 2 of Funding**
University 1, CH	Direct funding for partners in higher education	-
University 2, FIN	Indirect, EU	Direct, contract
University 3, FIN	Direct, international funding	Indirect, from home country
UAS*, NL	-	-

*UAS = University of Applied Sciences

In Table 16 the ways of funding are not presented in order of importance.

Question 7 was about student projects which relate closely to application development where applications are typically developed in projects. The results showed that not all companies used student projects as a form of international interactions. The frequency and types of student projects can be seen in Table 17.

Table 17. Types of student projects from the industry perspective

Company, Country	**Type 1 Student Project**	**Type 2 Student Project**	**Type 3 Student Project**	**Type 4 Student Project**
Company 1, CH	Research subcontract	Scholarship	Interns	Open projects in company-university clubs
Company 1, FIN	-	-	-	-
Company 1, FIN	Projects	-	-	-
Company 4, UK	Donation of tools or chips	Internships	Funded doctoral projects	-
Company 2*, FIN	Theses	-	-	-
Company 3**, FIN	Theses	Collaboration on research	-	-

In Table 17 the types of student projects are not presented in order of importance. The company respondents 2* and 3** answered only on behalf of the company in Finland.

As can be seen in Table 17, student projects were a form of international interaction in over half of the answers of the companies. An interesting detail was that final year projects and theses were reported as a form of interaction in only 2 responses. A reason for this could be that in some responses the position of the respondent might have been such that he/she was not involved in theses projects. In Finland theses and related projects are a very common form of interaction between companies of all sizes and higher education.

In most higher education responses to question 7, student projects were mentioned as a form of international collaboration with the IT industry, as can be seen in Table 18. According to one response student projects only occur on the national level.

Table 18. Types of student projects from the higher education perspective

Institution, Country	**Type 1 of Student Project**	**Type 2 of Student Project**	**Type 3 of Student Project**
University 1, CH	Circuit design	Algorithm design	Contour design
University 2, FIN	On national level only	-	-
University 3, FIN	Theses	Seminars	Research projects
UAS*, NL	Internships	-	-

*UAS = University of Applied Sciences

In Table 18 the types of student projects are not presented in order of importance.

Question 8 was about training of students in the form of industrial placement or summer job being a part of collaboration with higher education. As Table 6 in Section 3.3.2 indicated, in the program data analysis, a minority of the companies had training as a form of international interaction. In the interview responses all the internationally interacting companies saw training as a form of collaboration. The frequency and types of training provided by the companies can be seen in Table 19.

Table 19. Training as a form of industrial placement or summer job from the industry perspective

Company, Country	Training Done Yes/No	Training Type 1	Training Type 2
Company 1, CH	Yes	Mobile platforms	Short and long term training
Company 1, FIN	Yes	One to two months, industrial practice	-
Company 1, FIN	Yes	Strategic internship for doctoral students, 4-8 months	-
Company 4, UK	Yes	In summer 10% of headcount in Europe are students	-
Company 2*, FIN	Yes	Trainees all the time	-
Company 3**, FIN	Yes	Trainees and internships, 3-6 months	-

In Table 19, the training types are not presented in order of importance. Company respondents 2* and 3** answered only on behalf of the company in Finland.

In their responses to question 8, only half of the higher education respondents saw training as a form of international interaction, as shown by Table 20.

Table 20. Training as a form of industrial placement or summer job from the higher education perspective

Institution, Country	Training Done Yes/No	Training Type 1	Training Type 2
University 1, CH	Yes	Solving practical problems	-
University 2, FIN	No	-	-
University 3, FIN	Yes	Summer training in industry	Receive international trainees
UAS*, NL	No	-	-

*UAS = University of Applied Sciences

Question 9 was about the participation of companies/universities in the advisory boards of universities of applied sciences. The responses to this question seemed to vary. One reason for the variation could be that the respondents might not have been involved in the advisory boards. However, participation in the advisory boards of universities of applied sciences was an international form of interaction in less than half of the responses. On the other hand the responses showed that the UK-located company participated in the advisory boards of 100 universities worldwide to provide advice on industry trends and needs. The respondents from higher education, in their responses to question 9, did not see their participation in the advisory boards of universities of applied sciences as a form of international interactions.

Finally question 10 concerned publications as an outcome of collaboration. In the program data, Table 6, publications were seen as a form of international interaction. Table 21 below shows the company responses where some form of publications seemed to be very typical as an outcome of collaboration.

Table 21. Publications as an outcome of collaboration from the industry perspective

Company, Country	**Publications Done Yes/no**	**Type of publications**
Company 1, CH	Yes	Academic conferences, journals
Company 1, FIN	Yes	Publications
Company 1, FIN	Yes	Publications, majority scientific papers
Company 4, UK	Yes	Doctoral level academic papers for specialist conferences
Company 2*, FIN	Yes	Bachelor’s, Master’s, doctoral theses
Company 3**, FIN	-	-

In Table 21, company respondents 2* and 3** answered only on behalf of the company in Finland.

Almost all the industry respondents reported that publications were an outcome of their collaboration with higher education. Not all publications were academic papers. However, especially in Finland, on the national level, theses are common.

In their responses to question 10, all university respondents saw publications as an outcome of international collaboration as shown by Table 22.

Table 22. Publications as an outcome of collaboration from the higher education perspective

Institution, Country	Publications done Yes/No	Type of publications
University 1, CH	Yes	Derived from collaboration
University 2, FIN	Yes	Co-publishing with industry on national and international levels
University 3, FIN	Yes	Co-publishing of co-projects on international level
UAS*, NL	No	-

*UAS = University of Applied Sciences

However, the UAS respondent did not see publications as a form of international collaboration. This may result from the different focus of universities and UASs.

3.5 Summary

The first analysis in this study was done to find forms of interactions based on the findings of country-specific studies forming the secondary data. The second analysis addressed the document data of the collaboration programs, forming the primary data, regarding different forms of international interactions in the global programs analyzed. The third analysis addressed the interview data, used as complementary primary data, related to the case companies and four higher education institutions. The interviews were conducted for triangulation purposes to confirm the information reported by the case study companies in their documents. The general findings of the analyses supported each other, but also some deviation (discussed in more detail in Chapter 4). However, the responses may also depend on the respondent's position in the company, whether related to research or development.

The data analyzed in this study were based on existing global collaboration programmes, and the documents from which the data was gathered were public information at the time of analysis, which contributes to the reliability of the studied material. The interview data analyzed here consisted of responses given by specialists working in the companies and three university professors and one senior lecturer, all involved in collaboration between industry and higher education. However, they participated in the interviews as individuals, not official representatives of their companies or universities.

4 RESULTS AND DISCUSSION

4.1 Results of Analyses

In this study the different forms of international interactions between the IT industry operating in Finland and engineering education were studied, within the analytical framework consisting of the concept of network and the model of knowledge production. After examining forms of country-specific interactions between industry and higher education, based on previous studies (Section 2.2), a question was raised: how do forms of interactions change if the collaboration takes place on the international level, and what forms of interactions have evolved in global collaboration on the international level between the IT industry and engineering education? This study aimed to provide some answers to this question in the framework chosen.

The research problem which this study aimed to solve was the following:

- *What forms of interactions have been created between the information technology industry and engineering education to support their international collaboration?*

The context of this study was global collaboration, specifically collaboration between global IT companies operating in Finland and universities in various countries, and the study concentrated on examining and analyzing the different international forms of interactions.

In this section the first research question in relation to the results of the study is discussed. The second research question is considered in Section 4.3.

The first research question was: *What are the main forms of international interactions in existing global collaboration programs and networks between the global IT industry and engineering education in contrast to country-specific forms of interactions found in existing literature?*

A summary of country-specific forms of interaction based on secondary data is one of the results of this study. A large number of studies and their findings were reviewed to find out the main forms of interactions on the country-specific level. The theme analysis of secondary data showed that the main group of interactions on the country-specific level was knowledge transfer in various forms. There were also some indications of recruitment and funding interactions. Table 5 presents the found forms of interaction forms after theme analysis of secondary data in detail.

The results from primary data analyses showed converging trends compared to the results of secondary data analysis. The program data analysis showed that the main forms of international interactions were knowledge transfer, human resources recruitment, and funding acquisition but in contrast to country-specific forms of interactions, the number of different forms of interactions seems considerably smaller. The interview data analysis seemed to confirm these results. In the following the results of the primary data analyses are presented in more detail. The viewpoint in all the analyses was the viewpoint of the IT industry.

The main themes from the program data analysis and the analysis of the interview data is here further divided into sub-forms, because the interactions can be considered to have several goals and partly because the forms of interactions might be interlinked. The main forms of interactions are described below based on the forms of interactions they contain.

The thematic analyses showed that the data from the global collaboration programs and the interview supported each other well but there were a few deviations. An example was publications: in the responses to the interview the number of indications of the interaction was higher than in the program data results. A reason might be that in research publications are common, but in development they are a less common output, since the results of development are usually prototypes and new applications. In comparison, in two previous studies on international collaboration (discussed in Section 2.2.2) the importance of publications was considered. The finding of one study study (Okubo & Sjöberg 2000, 84) was that international publications in engineering and technology were produced with company participation in one fourth of the studied material. However, the publications were produced in Sweden in 1995 and the study had a university perspective. In the other study (Leydesdorff & Wagner, 2008, 320-321) it was found that the network of international collaborations in science has grown quickly after 2000 as measured by co-authorship of produced publications.

The main forms of international interactions according to the results of the program data are presented below and they are compared with the interview data to see how the results support each other.

Knowledge Transfer

The main forms of international interactions seemed to be knowledge transfer according to both the program data and interview data analyses. Thematic analysis of forms of interactions related to knowledge transfer yielded two sub-forms, direct knowledge transfer and indirect knowledge transfer. The terms used, direct and indirect knowledge transfer, have also been used in previous studies but not in the context of global collaboration (see e.g. Wakefield, 2005; Choi and Johanson, 2012). Knowledge transfer seemed to assume several forms and be unidirectional or bidirectional. Companies transferred knowledge to higher education, because they wanted the students and graduates studying IT to familiarize themselves with the technologies and tools the companies represented and used. Knowledge could also be transferred in the case of the IT industry from higher education to companies. Such cases related to innovations and applications.

Direct knowledge transfer appeared to be in the form of student projects producing new applications and knowledge, consultation, contract research and technical data transfer. Consultation and contract research could be considered bidirectional interaction, because information flows bidirectionally between the IT industry and higher education. Student projects were focused mainly on application development. Out of the program data studied a half had interaction with higher education in the form of student projects. Furthermore, Case 1 collaboration programs were project-form programs, focusing on innovations with higher education. The company also had application development collaboration programs with a focus on information sharing and knowledge transfer in the form of technologies and tools. This form of collaboration was intended to attract high-ability students, but also to transfer knowledge. In the interview responses of higher education student projects were reported as a form of interactions, whereas of the industry respondents no-one reported student projects as a form of interactions.

An example of direct knowledge transfer was also given by Case 3 program which seemed to focus on application development in student projects. This was to facilitate knowledge transfer and let students learn new technologies related to the company. Other reasons were to harvest innovations and to attract high-ability students. A further example was Case 4 program whose goal was to stimulate inventiveness of students especially when they were using the products of the host company. For companies a goal could also be to make the technologies and tools produced or used in the companies known among students. For example, if after graduation a student produces a design for the employer, the threshold to learn new tools and technologies is higher than to use the technologies and tools which the student has come to know during internships and education. Technical knowledge transfer as a form of interaction can be considered to be one form of marketing. A company transfers information, for example related to manufactured components.

In *indirect knowledge transfer* the interaction is mostly bidirectional and the goal of interaction is not pure knowledge transfer, but, for example, prototyping or gaining experience without a marketing goal of new technologies. Indirect knowledge transfer as an international form of interaction seemed to be slightly less common than direct knowledge transfer according to both the program data and interview data analyses. A form of indirect knowledge transfer appeared to be training and internships. For example Case 3 program used training and internships for application development and Case 4 program also offered jobs for interns as a form of interaction with higher education. Another form of indirect knowledge transfer seemed to be regional academic forums: a minority of the host companies of the programs interacted with higher education by participating in regional academic forums. Furthermore, participating in advisory boards appeared to be a form of indirect knowledge transfer, especially from industry to higher education, related to emerging technologies, and for example host company of Case 4 program participated in advisory boards of the engineering degree programs at UASs. It is a common form of interaction for example in Finland.

An additional form of indirect knowledge transfer appeared to be publications related to joint research on topics agreed with industry. However, in the program data only one company reported publications to be a goal of collaboration. On the other hand, most of the higher education respondents interviewed perceived publications as an outcome of collaboration with industry, and in the interview responses also all industry respondents indicated publications to be an outcome of collaboration. Furthermore, in some countries it is common to produce theses in engineering education for industry, but because of its local nature thesis preparation was not included here as an international form of interaction between industry and higher education. However, in some cases it could be included because sometimes final year projects and theses are carried out in countries other than the location of the head office of the industrial company. Thesis writing was only mentioned in Case 3 program data. Recruitment is possibly the main reason companies offer thesis tasks to selected students. However, in the interview responses there was no mention of theses as a form of interaction.

Human Resources Recruitment

Human resources recruitment appeared to be one of the main forms of interactions according to the results of the program data analysis. The recruited high-ability employees, representing the best in the best capabilities in the world in the latest technologies, seemed to give companies a chance to succeed in the increasing global competition in the IT industry. In this study, human resources recruitment was further sub-themed into direct and indirect recruitment.

Direct recruitment refers to employing new employees through collaboration. In collaboration projects the participating students may show the skills and competences the employer values. Direct recruitment may be marketing the company as a good employer and in some cases inform graduates about vacancies in the company. In all the program data cases analyzed, direct recruitment was reported as a form of interaction. Also interview responses by industry included direct recruitment as a form of interactions. However, in the higher education responses there was no mention of recruitment.

Indirect recruitment could be combined with different training and student projects. This was overlapping to some extent with knowledge transfer in this study. Training and student projects may include monitoring of students for future recruitment purposes, and therefore such forms of interactions might be considered recruitment. As indirect recruitment could be regarded international trainee programs and development programs because recruitment was not the main focus of the interactions. For example, in the trainee program of Case 2 host company the participants were selected for the international trainee program if they had performed well above average in their studies. Another example was Case 3 host company which offered different development programs for prospective employees. Also, in Case 4 host company, international partnerships and programs were among the goals to attract high-ability graduates particularly from the United States.

Funding Acquisition

Another main form of international interactions was funding acquisition according to the results of the program data analysis. Funding acquisition in collaboration programs usually meant transfer of funds to increase the chances of a higher education institution to research something of great interest to the funding institution. Funding acquisition seemed to assume the form of tools and materials for research or application development purposes. Funding was included to some extent in contract research themed above as knowledge transfer, because contract research and development in higher education, according to the contract mode, was usually performed on industry funding. Because collaboration between a company and universities was mostly direct collaboration, the role of governments in funding the collaboration was minimal.

Half of the cases analysed interacted with higher education through funding and the ways of funding acquisition seemed to vary. The ways of funding acquisition by industry included various types of donations, for example grants, joint partnership programs and direct research commissioning. The main category of funding acquisition can be divided into direct funding and indirect funding. The program data analyzed indicated only direct funding: industry donated funding for higher education. This was confirmed by the industry responses. However, among the interview responses from higher education also indirect funding was mentioned in one response. The European Union funding was given as an example.

The found forms of international interactions between industry and higher education presented above are summarized in Table 23 below.

Table 23. Forms of international interactions as analyzed into larger themes

Findings in order of most frequent occurence	**Main forms**	**Sub-forms**
1.	**Knowledge Transfer**	**Direct knowledge transfer** **Indirect knowledge transfer**
2.	**Human Resources Recruitment**	**Direct recruitment** **Indirect recruitment**
3.	**Funding Acquisition**	**Direct funding** **Indirect funding**

In Table 23, the interaction forms are summarized in order of frequency of occurrence in the present study and grouped into three main forms of interactions and six sub-forms according to the preference of industry**.** However, the data of the study was to some extent limited and thus the order of the frequency of occurrence might be different with more extensive data or with data from different collaboration programs.

Summary

In global collaboration between industry and higher education knowledge transfer seemed to be one of the most common forms of international interactions. Interviews with industry and higher education respondents confirmed this. Knowledge was transferred both directly and indirectly. However, the large global IT companies as host companies of the cases of this study seemed to have research and development offices increasingly in various countries and thus knowledge transfer was also taking place on the country-specific level without crossing borders. Human resources recruitment, another common form of international interactions, was also increasingly taking international forms, and its role in international collaboration seemed to be growing in importance. This was also confirmed by the interview responses. The results showed that human resources recruitment was mainly taking place in the form of direct recruitment since companies were searching for prospective high-ability employees. Finally, in the collaboration programs direct funding acquisition was considered an important form of international interactions. Funding acquisition in global collaboration was international and appeared to be taking different forms, which were often fairly concrete. Indirect funding, for example by the European Union, was also practised in Europe. Funding as a form of interactions was included also in the interview responses.

The results of the analysis based on the program data yielded forms of interactions to support global collaboration. According to the results, over half of the host companies of the analyzed collaboration programs practised knowledge transfer, recruitment, and different types of funding as forms of international collaboration. The analysis based on the interview data supported the findings of the program data analysis.

4.2 Discussion of Forms of International Interactions

This section provides a comparison of the results of this study and the results of country-specific forms of interactions, which were used as secondary data and theme analyzed for reference in Section 3.2. Furthermore a discussion of the study results in view of the analytical framework is included.

Comparison of the study results with the found country-specific interaction forms for reference

In the following the forms of international interactions, presented in Section 4.1, are compared with country-specific forms of interactions for reference, in order of the results of this study. The purpose of the comparison is to see whether the results of this study support those of previous country-specific studies.

Knowledge transfer seemed to be an important form of interactions both in country-specific and international interactions where there seemed to be various forms of direct knowledge transfer. A difference was that the number of different forms was considerably higher in country-specific interactions. The fewer forms of interactions may partly be a consequence of the focus of this study, which is the IT industry and not industry in general. Another difference was that indirect knowledge transfer in country-specific forms of interactions included forms that were not present in the international program data. Examples of such forms included building science parks, research centres and spin-offs, and also sabbaticals. Also in the analyzed models for country-specific forms of interactions (Table 5), the different interactions relating to knowledge transfer, and especially to licensing and research and development, were found to be the main forms of interactions between industry and higher education.

Human resources recruitment seemed to be practised both in international and country-specific forms of interactions which both included direct and indirect recruitment. The role of this form of interaction was of similar importance in both analyses.

Funding acquisition appeared to be the third most important form of interactions in both analyses. In international forms of interactions funding seemed to be mostly direct funding between industry and higher education. However, in country-specific forms of interactions funding mechanisms appeared to be more variable and invisible and also included indirect funding acquisition. Furthermore the role of government in funding acquisition in country-specific forms of interactions was considerable unlike in international forms of interactions.

Previous studies related to international forms of interactions were also considered (Section 2.2.2), but the studies were few and did not examine interaction forms but other aspects of international collaboration. Thus they were not included in the secondary data and were not theme analyzed in this study. However, some interesting viewpoints emerged from the studies. In a study on the changing pattern of industrial scientific research collaboration in Sweden, Okubo and Sjöberg (2000, 96) found that Swedish companies showed an increasing trend to collaborate with research groups outside the country. Furhermore, Marginson (2010, 6978) observed that nations retain only partial control over their own projects in international collaboration.

To summarize, no significant differences were found between country-specific and international forms of interactions between industry and higher education. The differences were mainly in the variety of forms of interactions and the government-related mechanisms in funding acquisition. However, the current and future trend seems to be towards network-form collaboration programs which are becoming increasingly global. This trend was also expressed in the few studies on international collaboration: the changing nature of industry-university research collaboration (Okubo & Sjöberg 2000), free exchange and cooperation in higher education interactions between nations (Marginson, 2010), and international collaboration in science being a communications network with its own dynamics and being different from national systems (Leydesdorff & Wagner, 2008).

Discussion of the study results in view of the analytical framework

Similarly to economy and business, collaboration networks are becoming increasingly global. The selective globalization of science and technology is one dimension of globalization, and science and technology are critical components of the production process and also of the capacity for development of societies (Castells, 2001a, 9). Companies collaborate to get benefits such as new knowledge and workforce and in international collaboration often globally. This was also seen in the results of this study. The labor market is changing because of internationalization and the global search for talent makes highly-skilled labor move in the global markets (Castells, 2001a, 11-13). Companies used to have export departments to export products, but nowadays development and production may take place concurrently in several countries. The department of a global company in each country can be responsible for the development and production of the different parts of the company product. This may also be the direction in engineering education, operating as a global network to accomplish a joint task. Strong, active and high-quality institutions and companies benefit from a collaboration network, because they can manage and plan the collaboration while the weaker participants are learning.

The ways companies benefit from global collaboration networks can be seen from the results of this study in two ways. Global collaboration programs are organized by global IT companies to transfer knowledge and to recruit high-ability employees. Furthermore, the knowledge transfer is partly indirect knowledge transfer, with the purpose of making company products known globally. On the other hand, the benefits of collaboration for higher education and especially engineering education seem to be that knowledge related to the latest technologies is transferred from companies to universities. Another benefit in some cases is funding. A benefit also is that the network form of collaboration may support the exchange of specialists between higher education institutions and in that way increase the international mobility of researchers and students. However, the focus of this study was the forms of interactions and thus further analyses of the benefits of the participants in collaboration was beyond the scope of the study.

When considering the results of the study against the analytical framework, it could be argued that collaboration often seems to take the form of a network, in parallel with economy and business. The new economy described by Castells (2001a) is organized in networks: large companies form networks, small and medium-size businesses connect with each other forming networks, and networks connect to networks forming a network of networks. The new economy is forming a network globally on a technological and organizational basis. (Castells, 2001a, 10-13) A network-form society, described by Castells (2004), has similarities to the analyzed collaboration programs which follow a simple network form. The company forms the interconnecting main node in the network and the engineering education institutions form the nodes connected to the main node.

The node depends on the network, which is an open structure and able to expand without limits (Castells 1996, 470). Information flows take place in links of collaboration networks between nodes, often bidirectionally. As Castells (1996, 470-471) described in his concept of network, a collaboration network consists of nodes and information flows. Gibbons et al. (1994) modelled knowledge production in a heterogeneous system. Similarly, in the analyzed collaboration programs in this study, the nodes, companies and universities, are heterogeneous and thus form a heterogeneous system. This has similarities to electronics. In an electrical network, if there is higher voltage in one node of the interconnected nodes, the voltage difference will be distributed over all the interconnected nodes in relation to the goodness and resistance. However, in social contexts, social networks support communication and information transmission, according to Tomassini and Luthi (2007, 751). When transferred in collaboration networks**,** information flows can take the form of different interactions. The case programs analyzed in this study showed a pattern of international forms of interactions used by companies. However, the type and amount of knowledge differ depending on the type of the network and the nodes it consists of, that is, companies and universities. Collaboration networks can be formed of various higher education institutions, with different capabilities, and industrial companies, both forming nodes in the network. Information flows in the formed links between the nodes of the network. Institutions with different capabilities here refer to different institutions with different amounts of knowledge of the technologies used in collaboration. Information flows describe the transfer of knowledge in collaboration networks in different forms of interactions and differ depending on the institution participating in the collaboration network. This is discussed in more detail in Section 4.3.

4.3 Theoretical Considerations of Information Flows in Collaboration Networks

The second research question, which is discussed in this section, was the following: *How can the function of collaboration networks be described from a theoretical point of view to better understand the ways information flows in such networks?*

The theoretical description of information flows proposed here contributes to the analysis of social networks in that it provides a theoretical tool to describe the function of a closed collaboration network, such as an application development network. The models used in social sciences to describe networks typically describe the structure of a network and not the function. The function here refers to information flows in a network. Another contribution is that the description helps to understand how information flows in a closed network at a certain time point. Understanding this is important for further analysis and development of industry-university collaboration. This is especially important in knowledge transfer which, on the basis of this study, seemed to be a common form of interactions in both international and country-specific collaboration between industry and university.

In this section the flow of information in collaboration networks is discussed from a theoretical perspective. To understand the function of a collaboration network it is important to understand the ways information flows in such a network, considering the heterogeneous structure of the collaboration network. In the description suggested in this section, the analytical framework of the study is used to describe a collaboration network in general (Castells 1996; Gibbons et al. 1994) and in addition, an effort is made to apply the circuit analysis method from electronics to describe the flows of information in collaboration networks more precisely. The analytical framework of this study is not alone sufficient to describe the flows of information, such as knowledge transfer, which appeared to be the main form of interactions in global collaboration. The theoretical approaches forming the analytical framework (Castells 1996; Gibbons et al. 1994) do not describe the amounts of knowledge in the different nodes of a collaboration network, nor do they describe the function of the network or the directions and strengths of information flows. Therefore Kirchhoff’s current and voltage laws from electronics are borrowed here to describe the flows of information in collaboration networks. These laws from electronics have been previously borrowed for use for example in mathematical social sciences in a study dealing with cooperative games (Lange & Grabisch, 2009). In the following, a brief overview of collaboration networks in general is provided, followed by a proposal for a theoretical description of information flows.

4.3.1 Collaboration Networks

In this study a network is used to indicate a collaboration network, which is a network with established links between different players. A collaboration network is highly cliquish and its path length is short when the random rewiring probability of a network is low. A network made by a small probability is called a 'small-world' network. For example a scientific collaboration network has a small-world property. (Kim & Park, 2009, 8987) An application development network was selected as an example of a collaboration network in this study. A precondition is that no external information flows are connected to this closed network at the time point of the consideration. Thus, the network considered can be defined as a closed network which has no connections to external networks or sources of information at this specific time point. The time point when the network is studied is considered to be so short that the network retains its structure without changes in its characteristics and without new connections.

Because of the focus on the information flows in links and a different amount of knowledge in the collaboration fields of science in the nodes, and because of a closed system, Kirchhoff's current and voltage laws from electronics (Millman, 1979, 708) were selected for describing the function of a collaboration network in this study. The laws are applied in the description of information flows in an application development network at a certain short time point (Section 4.3.2). In electronics a network is defined to use linear passive elements such as resistors, capacitors and inductors in combination with voltage and/or current sources and solid-state devices (Millman 1979, 706). In technology an open system means a system where all parties can communicate with each other unrestrictedly. An example is Open Systems Interconnection Model (OSI, ISO 7498), which is a reference model for the comparison of different protocols in communications (Halsall, 1988, 206-207). As an example of an open network the Internet has evolved from a small network linking a few research sites into a massive worldwide network providing services such as the World Wide Web and email using open protocols (Camarillo and Garcia-Martin, 2006, 5).

A node in this study is used to indicate an institution which has resources for research and developing applications, usually in collaboration with other institutions through different links. Examples of such nodes in this context are universities, research centers and companies collaborating and interacting with each other. In social sciences nodes refer to for example human beings and different types of institutions participating in networking. Thus the participants can be members of several networks, perhaps each network having a different goal or vision. (See e.g. Castells, 2001a, 10). In electronics nodes are defined as points where two or more circuit components meet (Millman 1979, 708).

A theoretical consideration of collaboration networks (see e.g. Perc, 2010; Kim & Park, 2009) is included here to describe the information flows and the amount of collaboration-related knowledge in the different nodes of heterogeneous collaboration networks (see e.g. Millman, 1979, 708; Castells, 1996, 470; Gibbons et al. 1994, 167; see also e.g. Ottewill, Riddy & Fill, 2005). An important feature of a collaboration network is bidirectional information flows, formed of interactions, between the nodes of the network. The nodes of a collaboration network may have different knowledge potentials and thus generate different amounts and directions of information flows between the different nodes. This may be the motivating factor behind collaboration. In this description the bidirectional flows of information and differences in the knowledge related to the collaboration fields of science are described using the electronic circuit analysis method, that is, Kirchhoff's current and circuit laws. Between social networks and electrical networks many analogies can be seen, such as the nature of information flows and electrical currents, and different potentials in the knowledge in the collaboration fields of science and in voltages in electronics. Furthermore, in a joint research and development project the task should be considered from the perspective of the whole network. However, in electronics a device must operate also as a discrete device. Different currents flow inside the device and cannot be equalized because the different discrete components and nodes have different functions in the electrical system, that is, in the network. Similarly in collaboration networks, in a research or development project performed by different higher education institutions as a joint project, the institutions often have different roles, and hence a different amount of information flows between the institutions forming the collaboration network.

The institutions participating in a collaboration network are different in competences and the links between the institutions have different contents and strengths of the communication, that is, interactions, between them. The institutions bring specialized knowledge to the network and communication links can then be established with neighbouring nodes. In the collaboration network the different participants can share a joint development project focusing on the same goal on the same time schedule sharing the knowledge. Depending on the goal of the collaboration network organization, the development is controlled and managed in different ways. If the goal is to produce publications or to develop new technologies and applications, the management and ways of organizing projects may be similar to industrial projects including management boards. However, as pointed out above, communication between institutions may vary in volume and direction and also change over time in joint knowledge production in research and development projects between institutions, the nodes. The communication may depend on the role and further on the amount of knowledge and expertise related to the collaboration fields of science the institution has. The amount of communication may depend on the roles of neighboring institutions, with which the institution has a collaboration relationship. The neighboring institution sharing the same research or development goal must be capable of co-operating and understanding the new information delivered, and that can depend on the level of knowledge in the collaboration field of science, expertise and the role of the collaborating neighbouring institution, the node.

However, not all higher education institutions have the same knowledge level relating to the collaboration fields of science and education in joint research and development projects. Some institutions may have more knowledge and experience than others and thus may take on more advanced tasks. This means that the information flow between the partners, the nodes of collaboration networks, is not typically equal during joint research and development projects. Castells (2004) states that nodes may have a varying relevance depending on the time of the network, and the nodes can increase their importance for the network by processing and generating information more efficiently. The relative importance of a node also depends on its ability to contribute to the goal of the total network. (Castells, 2004, 3) Some institutions may receive more information than they can give. Also, the flows of information may take different paths depending on the role of the institution.

When considering the expansion of the collaboration network, it is important to note that an increase in the size of the collaboration network can increase the amount of the total communication and knowledge of the network-related researched topic. Every node has its amount of knowledge and resources relating to the relevant fields of science and participates in communication with other nodes using different links. In collaboration the knowledge is transformed jointly into another form by collaborating nodes and can be applied in a new way. For successful collaboration, the knowledge of the collaborating nodes, institutions and companies, must be applicable and the collaborating nodes must have the necessary capacity to process and apply the knowledge. This means that the collaboration network in the case of an application development network is an information transmission network, and the sum of the total knowledge increase in a closed network would be zero. It is the sum of the knowledge of all the nodes relating to the fields of science researched belonging to the same collaboration network. Only the diffusion of the collaboration network in size and external information flows will increase knowledge in the relevant fields of science in the network.

4.3.2 Theoretical Description of Information Flows

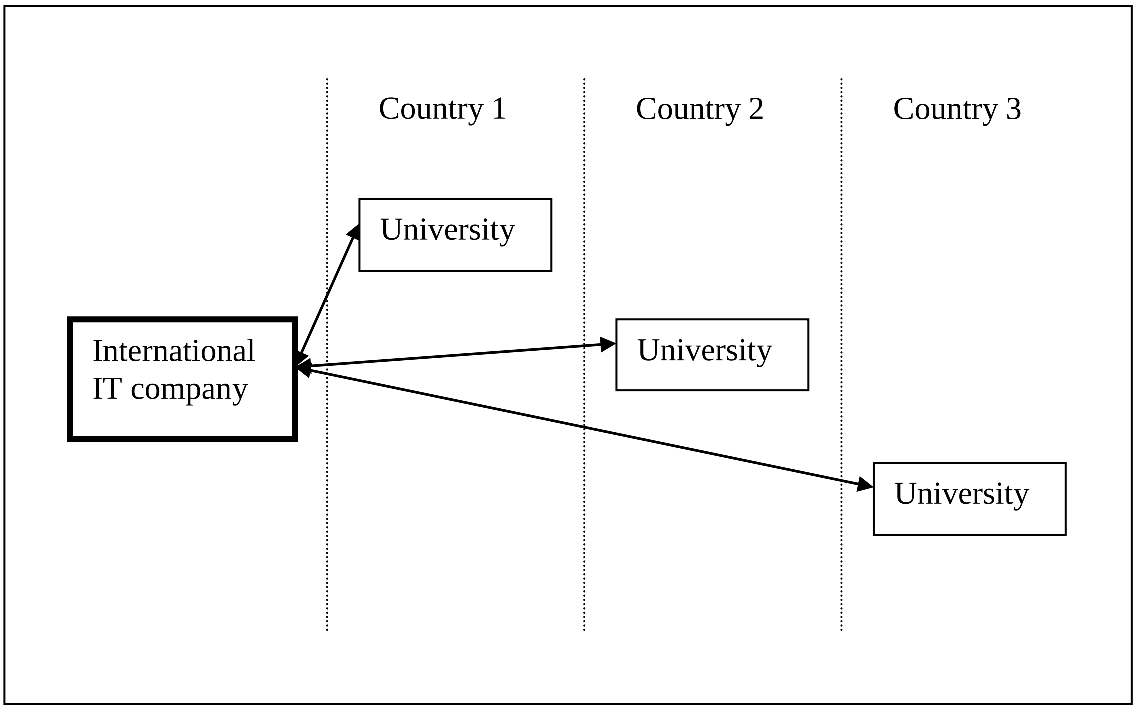
In this section the flow of information in collaboration networks is discussed from a theoretical point of view and further described by means of the circuit analysis method, that is, Kirchhoff's current and voltage laws, from electronics.

One previous study was found where Kirchhoff's current and voltage laws were applied to an aspect related to social sciences. Lange and Grabisch (2009) studied a case of classical cooperative games in the framework of network theory and applied Kirchhoff's current and voltage laws in order to find a new way to define the symmetry among players. (Lange & Grabisch, 2009, 321-332) It provides an interesting example of the use of Kirchhoff's current and voltage laws in social sciences but the example is not applicable in the present study because of the different nature of cooperative games and collaboration networks.

An effort is made in this study to apply Kirchhoff's current and voltage laws to describe, fully theoretically, the function of a closed collaboration network. A further analysis with data for demonstration is beyond the scope of this study. Different interactions can form information flows in different collaboration networks on both country-specific and international levels.

A description of information flows proposed here should be able to consider the heterogeneity of the nodes. Examples of nodes here are different companies and universities, which may have different amounts of knowledge and experience to be used for joint development in the collaboration field of science. The description should also be able to show the strength of information flows in the function of time between different heterogeneous nodes forming the network. Communication and the flows of information may differ considerably depending on the link and may change direction in the function of time. A collaboration network can, for example, be formed of one large global company and universities located in different countries, as illustrated in Figure 3 and as could be seen in the cases described and analyzed in Section 3.3. The company and universities are connected by bidirectional information exchange links.

Figure 3. Example of a collaboration network consisting of one global company and several universities located in different countries



In Figure 3 the collaboration system resembles a network with links between the interconnected nodes. The nodes can be companies and higher education institutions and in some cases also other types of institutions supporting collaboration.

The concepts used in this section, related to social sciences and electronics engineering are compared in Table 24.

Table 24. Comparison of the meanings of the network units

Unit	**Electronics Engineering**	**Social Sciences**
Flow	Electrical current	Information flow
Path	Electrical wire	Social link
Node	Connection point of wires	Institution, e.g. a university or a company
Potential	Voltage potential	Knowledge potential

Table 24 presents a comparison of the meanings of the units between electronics engineering and social sciences, showing the analogy between them. The units are used in the theoretical description of information flows proposed in this section.

The network system, the network of networks in this study refers to a combination of several networks where a university or a company may be a common point between different networks, possibly consisting of both universities and industrial companies. A higher education institution or a company, as a member of several application development networks, is a member of a network system, as shown in Figure 4.

Figure 4. Example of a network system consisting of three common links between two networks, a network of networks

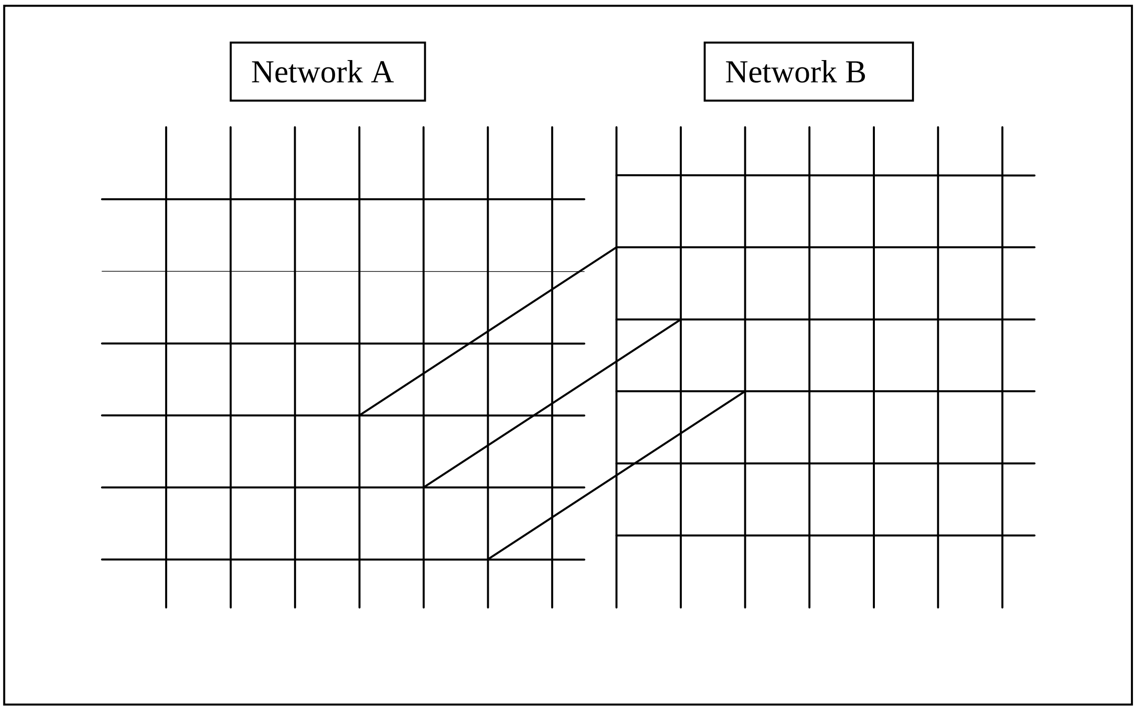


Figure 4 illustrates an example of a network system. In most real-life systems the connections between networks are more random and the system may consist of several networks which again may have connections to further networks. In this hypothetical example the three connections between the two networks illustrate links between two collaboration networks carrying information between them. The information flowing through the links may, for example, be information related to joint research or joint application development.

The Knowledge Production in Mode 2 model (Gibbons et al., 1994, 167) is applicable in this description where the system described may be very heterogeneous and focuses on application development rather than on science. Heterogeneity in this description means that the collaborating parties are different in nature because their focus and amounts of knowledge in the collaboration fields of science are different. The collaborating parties consist of different types of institutions, such as universities, universities of applied sciences, colleges, and industrial companies, participating in new application development in application development networks. Another reason for applying the Mode 2 model (Gibbons et al., 1994, 167) here is the focus of the model on the increase of communication in links. The description suggested below aims to show how the communication links between nodes, such as universities and companies, carry information in the collaboration network. The expanding network structure, with communication in links between nodes, thus increases the likelihood of finding new applications and innovations because of the increase in the total amount of knowledge in the collaboration fields of science and also because of increasing processing capacity. However, to illustrate the bidirectional flows of information, the analytical framework (Castells 1996; Gibbons et al.1994) of this study is not sufficient. It can be used to describe the overall collaboration network but not flows of information. Therefore the circuit analysis method from electronics is applied here to illustrate information flows and knowledge potentials in different nodes. This is related to knowledge transfer, which seemed to be the main form of interactions in global collaboration networks on the basis of the results of this study. Knowledge is transferred in various interactions forming information flows, and information flows are analogous to electrical currents. In electronics, the potential of a node generally specifies the voltage potential, the unit Volt. In this study it corresponds to the amount of applicable knowledge, knowledge potential, in a specific node of a collaboration network. The current in a link connecting nodes to each other generally means the electrical current, the unit Ampere. In this view it corresponds to an information flow and its strength between two nodes in a collaboration network. However it is difficult to measure the strength of an information flow without a commonly agreed method of measurement.

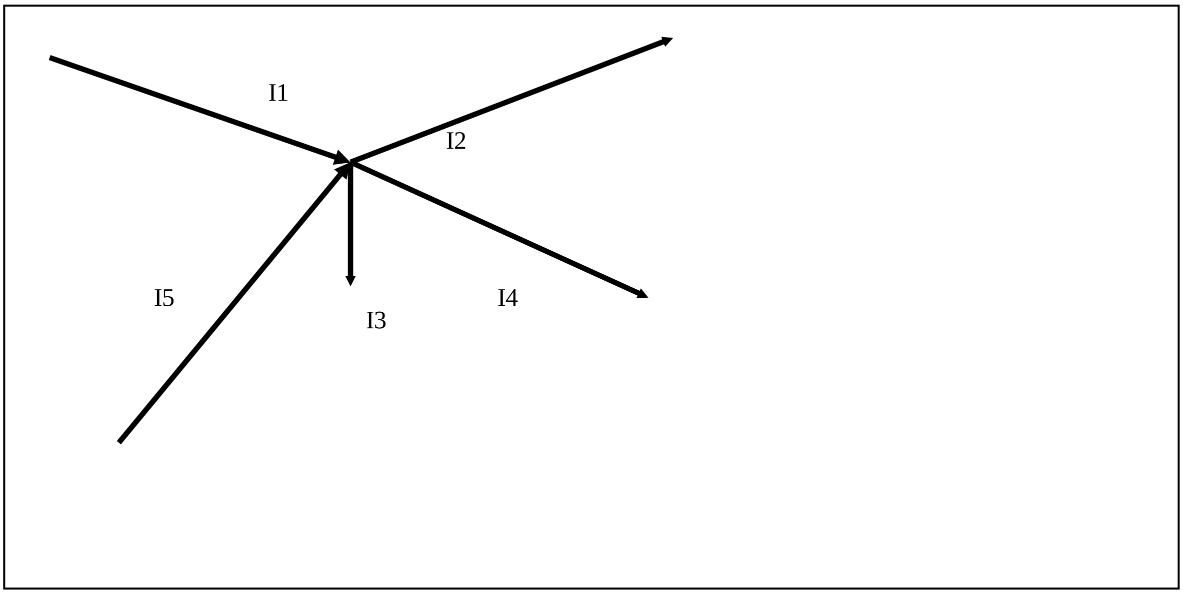
Electrical networks are generally circuit-analysed by using current and voltage laws, which are presented below. Kirchhoff's first law states: "*The sum of all currents toward a node must be zero at any instant of time*" (Millman, 1979, 708). A node in electronics is a point where electronic components are connected together, as in an application development network between industry and higher education, where a node is a place where flows of information meet each other and where there is knowledge of and interest in joint development. A university or an industrial company can form a node in an application development network. However, in electronics currents flowing into an electrical node may be different in strength and change direction depending on the time point. The electrical current between the nodes depends on the amount of resistance or reactance between the nodes and also on the difference in voltage between the nodes. Similarly, in collaboration networks the strength of communication between the nodes of the application development network depends on the closeness of collaboration and also for example on the difference in the amount of knowledge and experience related to the collaboration fields. Complex electrical networks with various components, loops and nodes can be suggested to be simulated using Kirchhoff's laws. The networks in electronics consisting of various nodes share the task of a network, similarly to a collaboration network. Electrical networks can be interconnected to each other, as also collaboration networks.

Figure 5 describes a collaborating node/an electrical node where several information flows/currents I with different strengths meet at a common point. Equation (1) shows that in a node the sum of the incoming information flows/currents in a collaboration network/electrical circuit equals the outgoing information flows/currents:

$$I2 + I3 + I4 = I1 + I5. \qquad (1)$$

In Figure 5 it is assumed that in the described node only application development is performed and there are no external knowledge flows towards the node.

Figure 5. A node of information flows in a closed application development network versus electrical currents in an electrical network



As Equation (1) above and Figure 5 illustrate, if outgoing flows of information in a collaboration network or analogically outgoing electrical currents in an electrical network have a positive sign, and incoming flows of information or electrical currents have a negative sign, then the equation presented can be written in the form

$$\sum I = 0. \qquad (2)$$

Equation (2) shows that no new information flows or electrical currents are generated in the node and the node combines and possibly re-distributes the information flows or electrical currents. The mathematical equation above is suggested to be applied to collaboration networks. The application development network, as a form of a collaboration network, is assumed not to contain external information flows but it uses information in a new way. The application development network, as a special case of collaboration networks, is considered at a certain extremely short time point and thus it is in a stable state without changing its structure or connections to external networks. Therefore in this study the application development network can be considered a closed network at that specific time point.

Kirchhoff's second law states: *"The sum of all voltage drops around a loop must be zero at all the times"* (Millman, 1979, 708). A closed path in an electrical circuit may be called a loop. Similarly, collaborating higher education institutions and industrial companies, cascading into each other in information exchange and forming a circle, can be called a loop. The nodes of an electrical loop may have different voltage levels. Similarly, different collaborating higher education institutions and companies forming a collaboration loop may each have different amounts of knowledge and experience related to the collaboration fields of science.

Furthermore, the total knowledge of a closed network can be distributed over several nodes in the network (Millman 1979, 712). This can mean that in an application development network the total knowledge relating to the collaboration fields of science of the network remains the same in application development without external information flows or network expansion and is distributed over the nodes of the network. Each node has its individual profile of knowledge and experience relating to the collaboration fields of science, as presented in Figure 6. This is analogous to an electrical circuit where the total voltage potential of a network is distributed over network resistors, and the voltage drops depend on the specific resistance of the resistor and current.

Figure 6. A description of information flows in a closed collaboration network

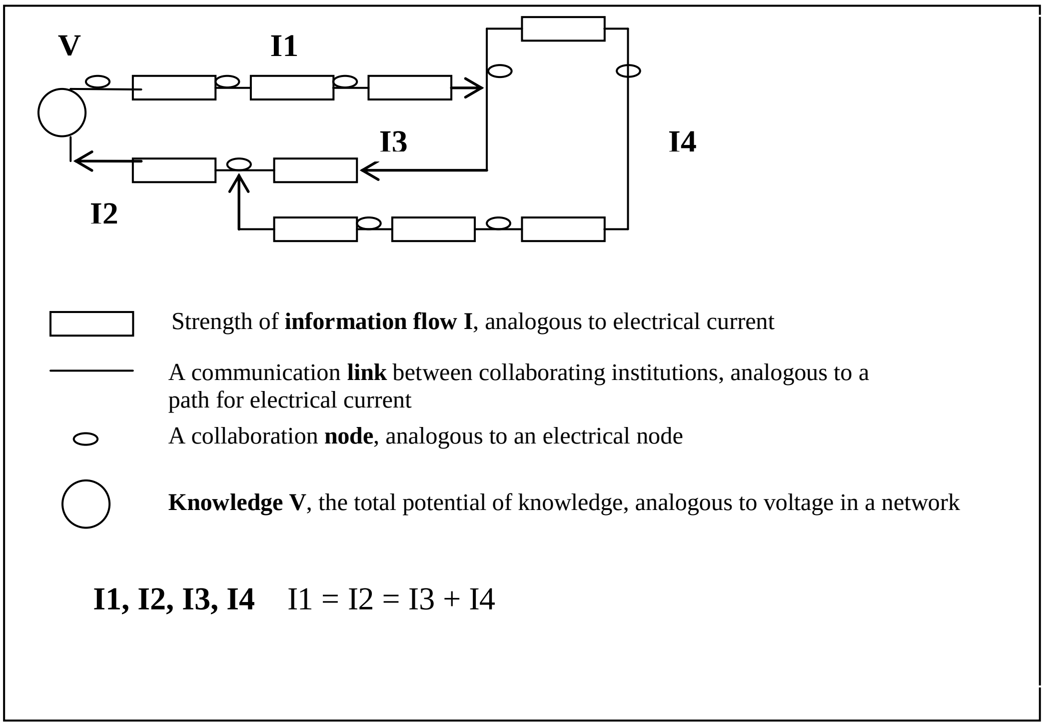


Figure 6 illustrates a description of information flows in a closed collaboration network parallel to an electrical network. In an electrical network there are resistors over which the total voltage V is divided, and electrical currents flow through the network, so that I1 is equal to I2 and further equal to current I3 added to I4. Resistors in an electrical network are components of resistance which is analogous to the closeness of collaboration in a social network between two nodes. Voltage V is the only source of voltage in the network, and all voltage drops in this network, when summarized, give voltage V. The amount of voltage, voltage potential, is analogous to the knowledge potential in a node in social networks.

As Figure 6 shows, in a closed collaboration network the strength of information flows in links refers to the amount of information exchanged. Knowledge V relating to the collaboration fields of is distributed over different types of the collaborating parties in the network, such as higher education institutions and industrial companies marked with ellipses. Other types of collaboration parties are also possible: the system may be very heterogeneous. The information flows from I1 to I2 and forms the communication strength for each part of the system. The greater the communication strength is, the higher the value assigned to information flow I. The network illustrated in Figure 5. is an example of a closed collaboration network, because the total knowledge V related to the collaboration fields, distributed over different collaborating institutions, is the same and there are no incoming external information flows. Networks of this type can be connected to each other to form a complex network system, a network of networks.

When considering the application of Kirchhoff's current and voltage laws to a theoretical description of information flows in collaboration networks, both strengths and limitations can be distinguished. As for the strengths, the description provides a clear illustration of the function of collaboration networks, whereas social sciences approaches focus more on different network structures. Furthermore, the proposed description provides possibilities to understand the strengths and directions of information flows as well as differences in the amounts of knowledge related to the collaboration field of science in the different nodes of the network.

A limitation of the description is that in collaboration networks the information flows can be more multidimensional than currents in electrical networks. Also, in the measurement of knowledge there is no agreed unit to measure the amount of the knowledge in a collaboration network, whereas in the case of an electrical network there is an agreed unit for voltage potential. Furthermore, in a collaboration network the probability of information to flow is more difficult to predict than in an electrical network. In a collaboration network there can be, for example, human and political reasons restricting information flows, despite a possibility to create interactions and have information to flow. These issues should be agreed on before collecting data and demonstrating the operation of the proposed approach in practice. Finally, it should be noted that this proposal is only applicable to a closed collaboration network .

4.4 Summary

To summarize the results presented and discussed in Chapter 4, knowledge transfer seemed to be the main form of international interactions among the global collaboration programs studied here, based on the primary data. This finding of the program data was in line with the interview data. In the analysis of this study knowledge transfer was further sub-themed into direct and indirect knowledge transfer, of which direct knowledge transfer seemed to be far more common. Human resources recruitment was found to be another common form of international interactions, but there were clearly fewer indications of its use as a form of interactions compared to knowledge transfer. Finally, funding acquisition was found to be a common form of international interactions among the studied global collaboration programs, but it was mentioned in the data as a form of interaction even more seldom than human resources recruitment. However, funding is a key issue in research and development and the reason for few indications of it in the data may be that all funding acquisition information is not public.

The findings of the secondary data analysis seemed to support the findings of the primary data analysis. Knowledge transfer was found to be the primary interaction form in the analysis of both primary and secondary data. However, the secondary data consisting of previous studies on country-specific forms of interactions included types of knowledge transfer that were not mentioned in the primary data consisting of the global collaboration program data. Short geographical distances and cultural match could be reasons for that.

Furthermore, a theoretical description of the flows of information in collaboration networks was proposed in this chapter. It is important to understand the ways information flows in collaboration networks to understand the function of such networks. This was described, in addition to the analytical framework of this study, by using methods from electrical engineering, more specifically electronics. Kirchhoff's current and voltage laws, that is, the circuit analysis method, were used to describe flows of information between the nodes of heterogeneous and closed collaboration networks, of which an application development network was used as an example. This description provides a view of heterogeneous collaboration networks, where also flows of information are heterogeneous, depending on the specific communication link and nodes at the ends of the link. Electrical networks, and similarly application development networks as one form of closed collaboration networks, can form a set of networks connected to each other in some nodes forming common points between the networks.

For example, if a higher education institution or a company is a member of several application development networks, they can form an interconnected system of networks. Thus flows of information from different networks meet in the interconnecting node and the node can benefit from all the flows of information.

A limitation of the proposed description of information flows is that currently there is no commonly agreed method for measurement of the strength of information flows in collaboration networks. Another limitation is that the description is proposed here for a closed collaboration network at a certain short point of time and without connections to outside sources of information. The strengths of the proposed description include that it takes the heterogeneity of the network into account and also considers the differences in the information flows in the network. Hopefully this description provides new perspectives for study of collaboration networks.

5. CONCLUSIONS AND RECOMMENDATIONS

The goal of the study was to find out the main forms of international interactions between the IT industry and engineering education. To reach the goal, existing global collaboration programs were studied using the available public program data as primary data. Also, additional primary data was gathered in the form of structured interviews from industry and higher education to see whether the responses were in line with the program data results. Furthermore, a literature review of previous studies was carried out to find out the used interaction forms in country-specific collaboration between industry and higher education because no studies were available on different international interaction forms. The gathered data was used as secondary data for comparison. Both the secondary and primary data were theme analyzed.

The results of the primary data analysis showed that knowledge transfer and human resources recruitment were the main forms of international interactions between the IT industry and engineering education, and funding acquisition was found to be another common form of international interactions. The perspective of the study was that of the global IT industry, and the host companies of the studied collaboration programs were operating and collaborating actively in Finland. The results were further compared with the results of the analysis of country-specific secondary data and no major deviations were found. Furthermore a theoretical description of information flows in a heterogeneous closed collaboration network was proposed in the study. Information flows were described theoretically by applying Kirchhoff's laws from electronics engineering and in parallel the social network concepts of the analytical framework of the study. These results answered the research questions of the study and the goal of the study was reached.

The current and future trend seems to be towards increasingly global and network-form collaboration between industry and engineering education, with participants from different countries. Knowledge transfer appears to be the main form of interactions and therefore also the study of information flows becomes significant.

This chapter further concludes the strengths and limitations of the study and results, as well as the contributions of the study for engineering education and industry in general and for the development of global collaboration between them. Finally some suggestions for further studies are provided.

5.1 Conclusions

As for the strengths of this study, the study has significance for the development of engineering education, so that collaboration with engineering education and industrial companies in other countries would increase and the content and quality of the education provided would be harmonized with high-quality engineering education competences internationally. For industry and education developers this study provides ways to be used in the development of collaboration with global industry and engineering education. For politicians this study indicates the direction of development: increasing international networking and competition and decreasing the significance of national control in international collaboration. Finland, like many other countries in the western world, is facing global competition in industrial production, application development and innovations. The global competition is also increasing in the research of technologies. To keep industry in Finland and to share know-how, the solution could be a high-quality engineering education system interacting actively and internationally with industry and higher education institutions abroad. High-quality higher education and further high-ability employees are important assets in global competition.

This study highlights various significant issues such as development of globalizing engineering education and industry and the role of government in this process. These issues are briefly discussed below.

Different countries have established different systems and policies to support national innovation generation. Collaboration between industry and higher education, mainly in research, is supported by governments. As an example, the Japanese government focuses on the field of collaboration programs, and the possible forms of interactions range from unrestricted research grants to industrial parks where companies can establish a research team for several years in order to learn from university research (Fujisue, 1998, 380).

However, because of the integration of countries, such as European countries, and better communication options, foreign development and production have challenged domestic development and production. The new situation is that the best product of a country is not necessarily the best in Europe or in the world. Therefore, in the development and production the knowledge, labor costs, closeness of markets and availability of raw materials have become important factors. Technical knowledge, how to develop and manufacture competitive products, and also knowledge in business, how to manage and sell competitive products in comparison with other countries, have become especially significant. The ability to create new innovations for new products has also become an important factor for success in competition. Already now many companies collaborate and interact with higher education institutions in application development or through different knowledge transfer mechanisms internationally to gain benefits for themselves. Some companies, however, engage in knowledge transfer to produce applications for client companies.

In parallel with national attempts to increase innovation generation and to increase collaboration between industry and higher education, especially large international companies have established different types of programs to collaborate with higher education globally. Production takes place in countries which are close to the markets and labor costs are relatively low. Various research and development units have been established in countries with large customer potentials for the products of the company. This means that companies may develop and manufacture products in different countries for a single country or for global use, and there is no longer a single large factory developing and manufacturing products in one country for export.

On the other hand, the national interests of different countries are unclear if companies operate in different countries having development and production in those countries. The motivation for this type of operation from the companies' perspective is to access the best of the world resources at relatively low cost and probably close to the markets.

Thus the role of the government in a country receiving research and development and production is to support this new industry bringing new knowledge and funds. The role of the government of the country from which industry moves in pursuit of better resources is not so clear. Furthermore, there may be also direct international research collaboration between industry and foreign higher education where the funding for research and development is allocated to foreign higher education institutions by companies. In this case the control and role of governments in direct international collaboration between industry, and especially foreign engineering education, is unclear. To stay competitive, Finnish higher education institutions should maintain their high quality of education and increase global collaboration in research and education.

From the Finnish perspective several factors can be considered. In the past the Finnish IT industry was in the export mode, exporting products designed and manufactured in Finland. Now the IT industry, including the Finnish IT industry, is mainly globalized. Products are no longer necessarily designed and manufactured in Finland, but design and production take place in network-form companies in several countries in parallel, and the knowledge related to the specific technology of development projects exists in several countries. Furthermore, there are attempts to export Finnish education, and one solution could be a global education development network. In the future, the way of operation in education could be, as in the case of the IT industry, sharing knowledge between higher education institutions in different countries and co-developing global-level higher education by collaborating in the fields in the interest of each country of the global education development network. This could help Finland to stay on the global level of education by learning from the best in the world. It would also support the retention of Finnish industry in Finland and could have a direct effect on employment and future success in global competition. Furthermore high-level higher education would attract high-ability applicants globally and increase the probability of developing new innovations. Currently many countries are considering different national innovation systems, whereas global collaboration between higher education institutions and industries could be a step towards a global network, for example a global innovation network referred to by Chen (2004, 337). However, these are strategic choices for a country and it is difficult to predict the direction a country wants to take.

Networking with higher education institutions and industry in other countries in sharing knowledge and the results of co-development could be beneficial for Finland, since Finland is a relatively small country and has relatively modest resources in science and technology. This also means that the Finnish institutions participating in collaboration with foreign institutions should have sufficient education and resources to act as active nodes or partners in collaboration in various forms of interactions. A strong and knowledgeable partner in collaboration takes the lead and derives most benefits from collaboration. This would mean that the higher education policy of Finland should focus more on the quality of education and research productivity than on the number of graduates and postgraduates or the number of years spent on completing the studies. Also, international forms of interactions between Finnish higher education institutions and foreign industry and foreign higher education institutions should be supported financially to increase collaboration. All in all international collaboration with various forms of interaction can yield more benefits than drawbacks to all concerned.

Additionally, a new way to develop new technologies is to do it in networks and increasingly in international networks. Currently the development of new technologies and new applications takes place partly or totally in different countries. Globalization has been defined as an increasing autonomy of boundary-crossing financial, investment, and technology flows promoted by transnational corporations through exports, foreign subsidiaries, and strategic alliances (Väyrynen 1998, 627). The new economy is forming a network globally on a technological and organizational basis (Castells, 2001a, 11). Exchange of students and researchers are well-established forms of collaboration, but new forms of collaboration are more advanced and often in networks. Now and in the near future it will be important to share knowledge between trusted parties in international collaboration networks. No country should be outside the information flows of the latest technologies. In addition, sharing information means that the collaborating parties can also share the benefits of development.

Furthermore, industry communicates and develops applications increasingly with foreign companies and universities, and governments have fewer and fewer possibilities to control the direction and speed of such a development. Globalization as a "catalyst" (Jackson, 2008, 350) makes the world more integrated, and development in telecommunications and data transmission even boosts integration. The host companies of case programs in this study were global IT companies collaborating directly with universities in different countries with little or no governmental control. Many companies have subsidiaries, production facilities and research centers in several countries, but in some cases the interactions between industry and higher education mostly take place on the country-specific level. The fast development of technologies and companies' desire to recruit high-ability graduates and to harvest innovations drive companies to interact internationally with different higher education institutions. The labor market is also changing because of globalization. The recruited high-ability employees representing the best capabilities in the world in the latest technologies give companies a chance to succeed in the increasing global competition in the IT industry. Mostly it is impossible to predict if globalization can influence a nation's global competitiveness. Furthermore, globalization could be seen as a consequence of greater mobility of people and advanced telecom networks. What will the future of this development be - would it possibly be a totally and globally networked IT industry and higher education? What are the ways for higher education to integrate in industry-driven global collaboration networks and to benefit from them? The directions of this development remain to be seen in the future.

5.2 Reliability

The question of reliability is a major concern in empirical research. The objective is that another researcher should be able to repeat the research procedure with the same data and arrive at the same results and conclusions. Error and bias should be minimized in the study. (Yin, 2009, 45) Furthermore, when assessing the reliability of the study the following issues should be considered: does the study provide answers to the research problem and questions in a reliable way, and can the research results be transferred to another context? This study provided answers to both the research problem and the research questions, as noted at the beginning of this chapter. Furthermore, the program data as part of the primary data was public information at the time of the study. Also, the results of the program data analysis were in line with the interview data analysis, which contributes to the reliability of the study and results. The responses to the interview were received by email and thus they were documented and are reviewable. However, interview responses always include a human aspect as well as analysis and interpretation of any results. As regards the secondary data of this study, the findings were reanalyzed and reinterpreted for the purpose of this study. The secondary data consisted of published studies, published in peer-reviewed scientific journals. The results of this study on international-level interaction forms, based on primary data, are comparable to the forms of interactions found in the country-specific studies, analyzed in this study as secondary data, which supports the reliability of the findings of this study. On the other hand, generalization and transferability of the results to other contexts is limited. In general the purpose of case studies is not to generalize but to provide new knowledge about a particular phenomenon and therefore a case study research design was applied in this study. The new knowledge provided by this study also raises new questions for future research. Some of these questions are identified at the end of this chapter.

As for the repeatability of the study, considering the data, the time elapsing between the study and a possible repetition would be crucial since the data used was partly online documents**.** Online data, though public, is not permanent and can also be updated after use in a study. However, with exactly the same data the study would be repeatable using the same methods. On the other hand, the viewpoint in thematic analysis may differ from researcher to researcher and yield slightly different results. Thus, the study would be repeatable with the same research questions but the results might not necessarily be the same as in this study. Finally, the study has also some limitations. First, the data available for study was limited because there were only a few companies publishing information about their global collaboration programs with higher education. A reason might be that only a few such programs currently exist. Another reason might be that the programs are mainly bilateral and the information is not published. A reason could also be a competitive situation between companies, and also universities may be competitors with other universities. The competitive situation might make them reluctant to collaborate. As a result, it was not possible to find information about public collaboration programmes with several university participants and company participants. Another limitation was that the interview data gathered in this study was to some extent restricted: the interviewees could not disclose classified or company-sensitive information and they did not officially represent the companies in the interviews, that is, the viewpoints given in the responses were not official company viewpoints.

5.3 Contributions

This study has several contributions. It provides higher education and other relevant parties with new knowledge of international interaction forms from the industry perspective. The results of the study, that is, the found different forms of international interactions in global collaboration programs can be used for development of industry-university collaboration in general. When the forms of interactions are known, it could be easier to create new forms of interactions and further develop them, and also to find new partners for collaboration. Furthermore, knowledge of the various forms used in existing collaboration programs might make it easier to observe and follow the development of internationalization of collaboration. This is also related to internationalization and globalization of higher education in general. The results could be used by industry for further development of global programs in collaboration with engineering education. The results could also be used by higher education institutions for development of new international collaboration. Higher education developers could use the results as a source for planning new types of support mechanisms for increasing international and global collaboration between industry and higher education. Knowledge of new ways to control and increase international collaboration would also be necessary to protect country-specific interests in a suitable way, because in the global context governments have very little control. Furthermore, the gathered comparative data of country-specific interaction forms, as summarized in this study, could be used for comparison and development in industry-university collaboration on the country-specific level.

The different forms of collaboration discussed in this study can be used as examples to find international forms of collaboration for developing global collaboration programs and new forms of interactions. Also, increasing competition between higher education institutions increases the need to network, and increasing globalization of higher education increases the need to network globally. Furthermore increasing globalization creates competition. Globalization is taking new forms, and because of easy communication globally over different networks, the globalization development seems to expand. The interconnected local area networks and especially the Internet increase the opportunities for people to communicate and collaborate regardless of location. Wireless technologies further increase the ways to communicate and collaborate even on a mobile basis. This also provides new options in education, marketing, collaboration and also for developing new applications on an international level. Wireless technologies and the Internet are prerequisites for global collaboration and this is one reason why the studied phenomenon is relatively new and so far little studied since these technologies have been in wider use only since the 1990s. All this contributed to the importance of studying global collaboration and related international forms of interactions for further use in this development.

A contribution of the study is also that it provides knowledge of international forms of interactions of existing global programs, which provides a new view of the forms of the used interactions. Furthermore the study could be considered trendsetting for future collaboration, also in smaller companies and perhaps also in other branches of industry.
The host companies of the case programs of this study represented the major multinational IT companies operating in Finland. An observation in the study also was that the role of governments seems to change in controlling and managing collaboration due to the development towards direct international collaboration between companies and universities, thus leaving a weakening role for governments.

The study also provides a background for the consideration of networks and links in connection with global collaboration (see e.g. Castells, 1996). A large global company together with a university operating in the same country or universities in different countries may form links to a university-industry collaboration network. Other companies participating in the same collaboration system then form a collaboration network together with the company and university. Furthermore, higher education institutions may collaborate with several networks, forming a common node of different collaboration networks. The collaboration networks may be formed of higher education institutions with different capabilities and of industrial companies and other types of institutions. Successful collaboration requires knowledge of the function of networks and links formed between the collaborating parties, which form the nodes in the networks. However, collaboration may in some cases cause problems because of possible competition and a risk of leakage of sensitive information.

Furthermore, a description of information flows in a collaboration network was proposed in the study to enhance knowledge and understanding of the characteristics of collaboration networks from a theoretical point of view. Information flows were theoretically described in a collaboration network and the amount of knowledge in the nodes of the network, by using Kirchhoff's current and voltage laws from electronics engineering. As a contribution, the theoretical description of information flows in a collaboration network could be used to describe flows of information in various types of heterogeneous closed collaboration networks also beyond this study (see e.g. Gibbons et al., 1994). The description provides a new view for consideration of such networks and the flows of information in them, which might be increasingly important in future development of collaboration. The description would help to observe and design the networks and on the basis of that to further develop the function of the network. In addition, this study was cross-disciplinary in nature, which is a further contribution. The study combined viewpoints and theoretical models from both social sciences and electronics engineering.

Finally, a contribution of the study is also that it provides an industry point of view to the researched topic. This is not very common in the studies of this field. One reason might be that not many researchers in the field have knowledge and experience of both industry and engineering education, their ways of operation, networks, goals and nature. Furthermore, competition in science and development of technologies are becoming increasingly global, and although higher education could still be considered mostly national, the trend is towards global involvement also in education, such as various online courses offered recently by some universities on a global scale. Also international forms of interactions between different institutions are increasing and gaining importance and often taking the form of networks, which is one reason why the study of the changing environment is important. Furthermore, this study could be used by companies as a model providing examples of forms of interactions for establishing links with foreign higher education. This study could also be used by companies which have already established international collaboration with engineering education, but would like to develop the collaboration further by adopting new forms of interactions.

As a concrete example, collaboration between the Finnish industry, Finnish higher education and foreign higher education could be boosted by establishing separate institutions for building links between industry and higher education in technology. The purpose of such an institution would be to find, establish, coordinate, and support new links and networking possibilities between higher education, both in Finland and other countries, and the Finnish industry. The institution would gather together the interested parties, companies and universities, with their special interests and goals and find possible common goals.

5.4 Recommendations for Further Study

This study could serve as a starting point for further studies on forms of interactions between global industry and engineering education. It could also be a starting point to study how to optimize collaboration between industry and higher education on the international level.

As a recommendation for further study on international forms of interactions, a study using cases of collaboration and interaction in different countries could be conducted, to gain a more comprehensive view. Secondly the data could be analyzed in a synchronized way in parallel in many countries. Synchronization here means that the study would be coordinated and managed between researchers in different countries by using for example similar themes to analyze the cases. This would help to zero-set the bias between different researchers, companies and cultures of the countries. This approach could result in a more reliable analysis of interaction types of the studied cases at a certain time point. Furthermore, to study the development of collaboration, a study could be conducted in parallel in different countries at set intervals and thus the results of each study could indicate the direction of development. Interaction in my understanding is not continuously similar, such as knowledge transfer and human resources recruitment in different forms, but the strength of sharing and co-developing new applications and innovations continuously increase because the communication networks increase. Thus collaboration networks grow in many dimensions without any limitations.

Further study could also be conducted country by country to get a view of international collaboration interaction in different countries between industry and higher education. In such a study companies and higher education institutions could be first studied as separate cases and then the results could be combined and compared. However, there could be difficulties in comparing the results between countries because of cultural, governmental and researcher-related biases regarding types of interaction. On the other hand, a repeated study would give the direction of development in interaction country by country, which would yield international forms of interactions from each country's perspective.

The description of information flows proposed in this study could be developed further by conducting experiments on information flows. Methods for measurement of information flows should be developed. First, the events in a collaboration network or network of networks should be identified. Then the strength based on the events could be recorded in every link connecting the nodes of the collaboration network together. If the information flows from one node to other nodes, then the node donating the information should have a greater amount of knowledge of the field studied or collaborated in than the receiving node. By combining strengths and types of information flows including the direction of information flows, a better understanding of the function of a collaboration network or a network of networks could be achieved. This is analogous to a network analyzer used to analyze traffic in the local area networks of companies. In simulation there is one major problem to overcome, namely the human mind, which means the participants' willingness to collaborate in the function of time. This means that sometimes there could be good prospects for collaboration, but collaboration still does not take place for human reasons. On the other hand, sometimes collaboration is successful even if the conditions are not favorable, but there is willingness or other reasons to collaborate.

To conclude, carrying out this same study within the same analytical framework and set-up simultaneously in different countries and in different academic fields of engineering might make it possible to generalize the results to some extent. In such a study with multiple angles, there would also be possibilities to get new viewpoints for the analyses, because of cultural differences, varying degrees of governmental guidance and also possible differences in the thematic analyses of the findings.

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Appendix 1. Examples of publications produced in collaboration programs

Conference and reference	Title of paper	Authors
UBICOMM 2008 conference. Valencia, Spain, October 2008, (www.iaria.org/conferences2008/ProgrammeUBICOMM08.html;	Virtual P2P Environment for Testing and Evaluation of Mobile P2P Agents Networks	Balandin, S.,Leppanen, S., Turunen, M., Gorodetsky, V., Karsaev, O., Samoylov, V., Serebryakov, S.
UBICOMM 2008 conference. Valencia, Spain, September 2008,www.iaria.org/conferences2008/ProgrammeUBICOMM08.html;	Demo: P2P Agent Platform and Virtual P2P Environment for Testing Mobile P2P Agents Networks	Balandin, S. Serebryakov, S.
ruSmart 08. (http://www.rusmart.org/2009/programme.html;	Symbian - Smart Platform for Mobile Innovation	Zavorine, A., (Symbian Research, UK)
Wireless Personal Mobile Communication WPMC'08 (www.cwc.oulu.fi/WPMC2008/programme.html;	Near-Optimal Symbol Mapping for MIMO Systems With HARQ Protocols	Katsov, I., Kapralova, O., Evseev, G., Chernyshev, V., Kozlov, A.
Wireless Personal Mobile Communication WPMC'08 (www.cwc.oulu.fi/WPMC2008/programme.html;	Adaptive Power Saving on the Receiver Side in Digital Video Broadcasting Systems Based on Progressive Video Codecs	Belyaev, E., Koski, T., Paavola, J., Tiurlikov, A., Ukhanova, A.
Wireless Personal Mobile Communication WPMC'08 (www.cwc.oulu.fi/WPMC2008/programme.html;	Extended YUV Colorspace Transform for Lossless Image Compression	Minchenkov, V., Sergeev, A., Tiurlikov, A.
Wireless Personal Mobile Communication WPMC'08 (www.cwc.oulu.fi/WPMC2008/programme.html;	Tree Algorithms With Free Access and Interference Cancellation in Presence of Cancellation Errors	Andreev, S., Pustovalov, E., Tiurlikov, A.
Wireless Personal Mobile Communication WPMC'08 (www.cwc.oulu.fi/WPMC2008/programme.html;	Statistical Modulation for Low-Complexity Video Transmission	Sergeev, A., Tiurlikov, A., Veselov, A.
Wireless Personal Mobile Communication WPMC'08 (www.cwc.oulu.fi/WPMC2008/programme.html;	Orthogonal Bandwidth Request Codes for IEEE 802.16 Networks	Dudkov, A., Sayenko, A.
Wireless Personal Mobile Communication WPMC'08 (www.cwc.oulu.fi/WPMC2008/programme.html;	Bluetooth to WiFi Interference Detection for Multi-Radio Platform Optimization	Pustovalov, E., Kozlov, A., Srikanteswara, S., Maciocco, C.
IEEE Computer Society Ubicomm 09, (www.iaria.org/conferences2009/ProgrammeUBICOMM09.html;	Distributed Architecture of a Professional Social Network on top of M3 Smart Space Solution made in PCs and Mobile Devices Friendly Manner	Balandin, S., Oliver, I. Boldyrev, S.
WTS 2009, Wireless Telecommunication Symposium, Prague, 2009, (www.ieeexplore.org/xpl/mostRecentIssue.jsp?pumumber4977245;	Power saving control for the mobile DVB-H receivers based on H.264/SVC standard	Belyaev, E., Grinko, V., Ukhanova, A.
ruSmart 09, 2nd Russian Conference on Smart Spaces, (www.new2an.org/programme2009.pdf;	Anonymous Agent Coordination in Smart Spaces: State-of-the-Art	Smirnov, A. Kashevnik, A. Shilov, N. Oliver, I., Lappeteläinen, A., Balandin, S., Boldyrev, S.
ruSmart 09, 2nd Russian Conference on Smart Spaces, (www.new2an.org/programme2009.pdf;	Cross-Domain Interoperability: a case study	Oliver, I.
International Conference on Ultra Modern Telecommunications ICUMT'09, (www.icumt.org/2009/pro-final.pdf;	Temporal Scalability Comparison of the H.264/SVC and Distributed Video Codec	Huang, X.,Ukhanova, A., Belyaev, E., Forchhammer, S.
International Conference on Ultra Modern Telecommunications ICUMT'09, (www.icumt.org/2009/pro-final.pdf;	IEEE 802.16m Energy-Efficient Sllep Mode Operation Analysis with Mean Delay Restriction	Anisimov, A., Andreev, S., Turlikov, A.
CCNC 2010,7th IEEE Consumer Communications and Networking Conference. Las Vegas, USA, January 2010, (www.ieee-ccnc.org/2010/	MAEMO-based Scalable Platform for Construction of User-driven Social Location Based Services	Koucheryavy, Y., Balandin, S., Krinkin, K.

Appendix 2.

Questionnaire on collaboration between industry and higher education

25.08.2010

Please answer the questions in the spaces provided. The answers will be used as part of a doctoral dissertation. All the answers will be treated confidentially and the respondents' names will not be included in the dissertation.

1) What are the three main forms of international interactions your company is doing with higher education?
2) What are the reasons for the collaboration of your company with higher education? Give three reasons.
3) Is application development and application production included in your collaboration with international higher education? If yes, what kind of applications have been developed and produced?
4) What is the importance of collaboration with international higher education from the possible recruitment point of view?
5) What is the importance of collaboration with international higher education from the knowledge transfer (in either direction) point of view?
6) How does your company fund the collaboration with international higher education?
7) What kind of student projects do you have?
8) Is training of students in the form of industrial placement or summer job a part of your collaboration with higher education? If yes, what type of training do you offer?
9) Does your company participate in advisory boards (neuvottelukunta) at universities of applied sciences? If yes, what is your role in the board?
10) Are publications an outcome of collaboration with higher education? If yes, what type of publications have been produced?

Thank you for your cooperation

Appendix 3.

Please answer the questions in the spaces provided. The answers will be used as part of a doctoral dissertation. All the answers will be treated confidentially and the respondents' names will not be included in the dissertation.

1) What are the three main forms of international interactions your institution is doing with industry?

2) What are the reasons for the collaboration of your institution with international industry? Give three reasons.

3) Is application development and application production included in your collaboration with international industry? If yes, what kind of applications have been developed and produced?

4) What is the importance of collaboration with international industry from the possible recruitment point of view?

5) What is the importance of collaboration with international industry from the knowledge transfer (in either direction) point of view?

6) How does your institution receive funds from international industry for the collaboration?

7) What kind of student projects do you have with international industry?

8) Is training of students in the form of industrial placement or summer job a part of your collaboration with international industry? If yes, what type of training?

9) Does your institution participate in advisory boards (neuvottelukunta) at universities of applied sciences? If yes, what is your role in the board?

10) Are publications an outcome of collaboration with international industry? If yes, what type of publications have been produced?

Thank you for your cooperation