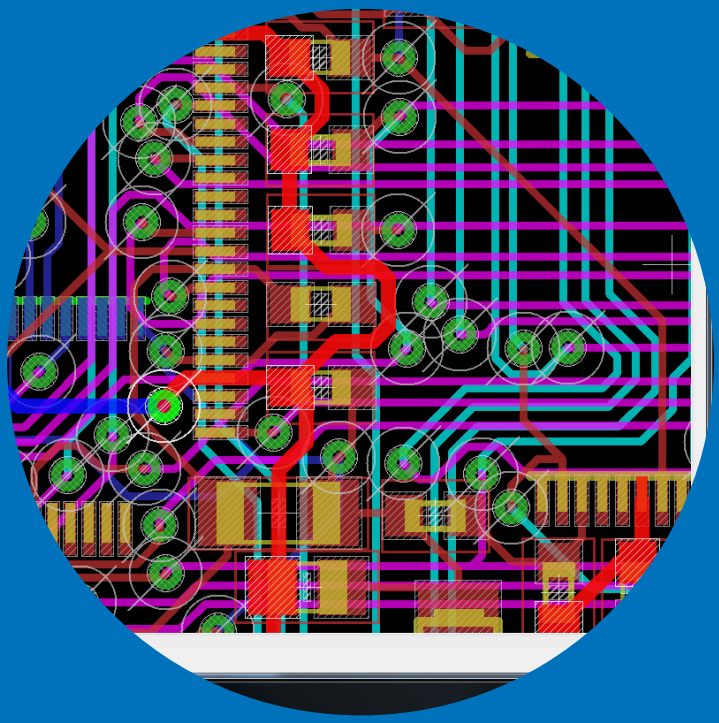
Department of Radio Science and Engineering

Becoming an electrical engineer: a mixed methods study of electrical engineers' studies and career

Kirsti Keltikangas



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Becoming an electrical engineer: a mixed methods study of electrical engineers' studies and career

Kirsti Keltikangas

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Images: A part of Aalto-1 satellite main computer's circuit board,
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Abstract

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Abstract

Engineers are regarded as analytic problem-solvers and experts in their specific technical fields. This substantive expertise is acquired during engineering studies, whereas personal and professional competences are largely adopted after graduation. The on-going changes in society require that such qualifications be learnt faster, and thereby technical universities need to 'produce' graduates with better qualifications for working life. Yet, there is not enough knowledge of how engineers gain the seeds in expertise and professional competences in higher engineering studies. Furthermore, universities need more research-based data on ways which professional competences could more effectively be integrated into the curriculum design.

This research examines electrical engineers, their education and careers. In particular, it describes experiences that electrical engineers have gained from their studies, expertise, professional competences, and careers in working life. The data for the study were collected and analysed with a mixed methods approach. Quantitative data were collected by means of survey questionnaires. The first survey (N=99) was sent to engineers graduated from the Department of Electrical and Communications Engineering at Helsinki University of Technology. The students at the Department (N=120) whose studies had been delayed, comprised the sample in the second survey. Finally, 12 interviews of graduated electrical engineers were conducted and turned into narrative stories with a qualitative, narrative approach.

The results show that a foundation in engineering knowledge is built during the university studies, when students in general adapt an engineering mindset and identity. Such learning draws from their scientific studies, for instance, in mathematics and physics. The findings suggest that the respondents in the surveys and in the narrative stories were generally satisfied with their studies at the Department. Still, they criticised mass lecturing and claimed that teaching should have been more interactive. They also expressed that students could be regarded more as individuals. The narrative stories reveal that electrical engineers in working life become experts but not necessarily in electrical engineering. They acquired new competences e.g. in financial management, HR, or budgeting, and currently manage a group of experts in their industry. The results indicate there is a need to enhance knowledge of pedagogies incorporating expertise and professional competencies more systematically into the engineering education.

Keywords engineering education, expertise, professional competencies, career

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Tiivistelmä

Työelämässä diplomi-insinöörejä pidetään yleensä analyyttisinä ongelmanratkaisijoina ja asiantuntijoina omalla alallaan. Perinteisesti tähän liittyvä asiantuntemus ja ammatilliset kompetenssit on valtaosin opittu yliopistosta valmistumisen jälkeen. Yhteiskunnassa meneillään oleva muutos vaatii näiden oppimista ja omaksumista nopeammin. Tämä asettaa haasteen yliopistolle kouluttaa sellaisia insinöörejä, joilla jo valmistuessaan on paremmat valmiudet toimia asiantuntijana. Tekniikan alan yliopistoilla ei ole kuitenkaan tarpeeksi tietoa siitä miten opintojen aikana luodaan pohja asiantuntijuudelle ja ammatillisten kompetenssien kasvulle. Yliopistot tarvitsevat myös tutkimustietoa siitä miten asiantuntijuutta ja kompetensseja voidaan paremmin integroida opetussuunnitelmaan.

Tämä väitöskirja tarkastelee sähköinsinöörejä, heidän opintojaan ja uraansa. Työ kuvaa erityisesti kokemuksia, joita insinööreillä oli opinnoistaan, asiantuntijuudestaan, ammatillisista kompetensseistaan ja urastaan. Tutkimuksen aineisto kerättiin ja analysoitiin monimenetelmäotteella (a *mixed methods approach*). Kahdella kyselylomakkeella kerättiin kvantitatiivista aineistoa. Ensimmäinen lomake (N=99) lähetettiin Teknillisen Korkeakoulun Sähkö- ja Tietoliikennetekniikan osastolta valmistuneille diplomi-insinööreille. Toisen kyselyn kohderyhmänä oli puolestaan Sähkö- ja Tietoliikennetekniikan opiskelijoita (N=120), joiden opinnot olivat viivästyneet. Lopuksi samalta osastolta valmistuneita diplomi-insinöörejä (12) haastateltiin ja haastatteluista tehtiin narratiiviset urakertomukset.

Tulosten mukaan diplomi-insinöörin opinnoista saadaan hyvä tekniikan alan yleissivistys ja pohja. Lisäksi omaksutaan insinöörimäinen ajattelutapa. Tämä perustuu tutkinnon luonnontieteellisiin opintoihin, esimerkiksi matematiikkaan ja fysiikkaan. Tulosten mukaan kyselyihin vastanneet ja haastatellut olivat yleensä tyytyväisiä opintoihinsa Sähkö- ja Tietoliikennetekniikan osastolla. He antoivat kuitenkin palautetta siitä, että opetuksen (muun muassa massaluennot) olisi pitänyt olla vuorovaikutteisempaa ja opiskelijoita tulisi huomioida yksilöllisemmin. Narratiivisten kertomusten mukaan diplomi-insinööreistä tulee asiantuntijoita työelämässä, mutta ei välttämättä juuri sähkötekniikan alalla. He oppivat uusia työelämätaitoja esimerkiksi taloushallinnossa tai budjetoinnissa ja johtavat asiantuntijaorganisaatioita. Tulokset osoittavat tarvetta saada lisää tietoa siitä miten asiantuntijuutta ja ammatillisia kompetensseja systemaattisemmin integroidaan tekniikan alan opetukseen.

Avainsanat insinööriopetus, asiantuntijuus, ammatilliset kompetenssit, ura

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Preface

This thesis was completed at the Department of Radio Science and Engineering (RAD) at Aalto University School of Electrical Engineering. The work was financially supported in part by the Aalto University Professional Development (Aalto PRO) and the School of Electrical Engineering.

I would like to give my warmest thanks to my supervisor, Prof. Ari Sihvola for his contribution and patience to the process of this thesis. I am thankful for his great expertise and effort during the dissertation process.

My instructor, Prof. Eero Ropo provided invaluable assistance and encouragement during this process. The stimulative discussions with him helped me to find the way through the cross-disciplinary and winding path with mixed methods, and particularly with the narrative approach.

I would like to thank Prof. Michael Christie and Doc. Risto Honkonen for their prompt and thorough work in acting as preliminary examiners. Their constructive comments were most valuable for my work. My thanks also go to Anya Siddiqi and Pia Lappalainen for the language corrections. I also wish to extend my thanks to my interviewees who participated in this research.

I want to thank Prof. Miia Martinsuo and Henrik Wallén for the opportunity to write joint articles during this process. With both of them, it was very joyful and encouraging to share the writing process. Furthermore, I wish to express my thanks to the numerous people at RAD, the Department of Electrical Engineering, the Department of Micro and Nanosciences, Aalto PRO, and the ELEC Study Administration. Especially I would like to mention Prof. Liisa Haarla, late Prof. Jorma Luomi and Prof. Jussi Ryynänen. Likewise, my thanks go to Antti Nuoreva for coding the survey questionnaires.

I am thankful for Prof. Jonte Bernhard for giving the opportunity to stay at ITN Norrköping (Institutionen för Teknologi och Naturvetenskap) at Linköping University. Furthermore, I would like to mention the members of the SÄMA study group – with you we could share discussions and challenges in cross-disciplinary research work.

My warm thanks go to my previous manager Anna-Kaarina Kairamo at Aalto PRO and my current managers Perttu Puska and Prof. Keijo Nikoskinen at the School of Electrical Engineering for their support and encouragement.

Finally, I would like to thank my family and friends who have shared ups and downs, to name a few: Arja, Heini, Kristiina, Lotta, Maikki, Pirjo and Sini. I wish I could have shared this day with my late parents Terhi and Matti; I am thankful that you existed in my life. I am deeply grateful to my children Katri, Juho and Antti for keeping me present in everyday life. Thank you for your patience and love. To conclude, I am utmost grateful to my husband Eero for his love, patience, and unconditional support when walking with me through all these years.

Otaniemi, Espoo, June 2013

Kirsti Keltikangas

Contents

List of abbreviations

Abbreviation	Corresponding name
ABB	ASEA Brown Boveri; global, publicly listed company in power and automation technologies
AEG	Allgemeine Elektrizitäts-Gesellschaft, a German producer of electrical equipment
APPLES1	Academic Pathways of People Learning Engineering Survey 1 (US)
APPLES2	Academic Pathways of People Learning Engineering Survey 2 (US)
APS	Academic Pathways Study
CAEE	Center for the Advancement of Engineering (in US)
CDIO	Conceive-Design-Implement-Organise; the global CDIO Iniatiative for engineering education programmes
CPD	Continuing Professional Development
CS	Computer Science
DeSeCo	Definition and Selection of Competencies: Theoretical and Conceptual Foundations (a project funded by OECD)
ECE	Department of Electrical and Communications Engineering at TKK (currently Aalto ELEC)
ECTS	European Credit Transfer System (according Bologna Declaration)
EER	Engineering Education Research
EERC	The Engineering Education Research Colloquies (in US)
ELEC	Aalto University School of Engineering Education
ETA	Faculty of Electronics, Communications and Automation (in years 2008–2010; currently Aalto ELEC since 2011)
HR	Human Resources
HRD	Human Resources Development
HRM	Human Resources Management
HSE	Helsinki School of Economics (current Aalto University School of Business BIZ)
ICT	Information and communications technology
IT	Information technology
NSF	National Science Foundation (in US)
OECD	Organisation for Economic Co-operation and Development
PIE	Persistence in Engineering (US project in engineering education)
R&D	Research and Development
SEFI	European Society for Engineering Education (Societé Européenne pour la Formation des Ingénieurs, www.sefi.be)

SPSS	Statistical Package for the Social Sciences; a computer software owned by IBM Corporation
STEM	Fields of study in the categories of science, technology, engineering, and mathematics
TEK	The Finnish Association of Graduate Engineers TEK (www.tek.fi)
TKK	Helsinki University of Technology (*Teknillinen korkeakoulu* in Finnish), established in 1849, emerged as a part of Aalto University in 2010
VTT	VTT Technical Research Centre of Finland (www.vtt.fi)
YOOP	University Pedagogical Training (15 ECTS) for teaching personnel organised at TKK during years 2001–2010

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1 Introduction

This study focuses on electrical engineers and their education. In particular, it describes experiences that electrical engineers have acquired from their studies, expertise, professional competencies, and careers. This research is interdisciplinary in several ways. First, it belongs both to the educational and engineering research traditions. Second, I have used mixed methods when collecting the research data and analysed it by resorting it to both quantitative and qualitative approaches. In addition, this work examines graduate adult learners as well as basic degree engineering students. The study can also be claimed to represent Engineering Education Research (EER) which is a fairly new discipline in Finland. However, in North America, Europe, and Australia it has already emerged as a globally connected field of inquiry (Lucena et al. 2008; Borrego et al. 2008; Haghighi et al. 2008; Jesiek, Newswander and Borrego 2009; Lohmann 2010; Borrego and Bernhard 2011; Johri and Olds 2011).

Furthermore, this research also partly centres on engineering profession and its implications for the surrounding society (cf. Michelsen 1999; Korhonen-Yrjänheikki 2011). The topic is linked to other studies in the global EER field. Prior research, particularly in the US, has focused on engineering education and the kind of roles engineers will play in the future, and the concern that they may not be appropriately educated to meet the demands of the 21st century (Gabriele 2005; Educating the Engineer of 2020, 2005, The Engineering Education Research Colloquies 2006). Furthermore, the number of students in engineering education the in the US has declined, and thereby the local engineering universities attempt to improve their quality of education and stay competitive (Gereffi et al. 2008). The universities of other Western countries assumably share similar concerns.

There is evidently a need to review the role of engineers and engineering education due to the rapid technological change in the global society. Bordogna (1997) claimed already in the last millennium that "tomorrow's engineers will need to use abstract and experiential learning, to work independently and in teams, and to meld engineering science and engineering practice". He has added that engineers "must exhibit more than first-rate technical and scientific skills", and also "have a broad, holistic background". (ibid. 1997.) Meier, Williams and Humphreys (2000, 377) have stated that "the workers of the 21st century must possess cross-functional interdiscipli-

nary knowledge, skills, and attitudes, which extend well beyond the traditional scope of technological training". Furthermore, engineering requires solving problems that are ill defined, likely nonlinear, multidisciplinary, and complex, with various possible solutions (Gabriele 2005, 286).

The present research was instigated at Helsinki University of Technology (TKK) which had been originally established in 1849. I collected the research data for this work at TKK Department of Electrical and Communications Engineering (ECE). At that time, TKK's Strategy 2015 stated that one of the ideals of higher education at TKK is *"to appreciate creativity, critical thinking and high-standard expertise"* (TKK Strategy 2015). This should be attained by providing top-level teaching based on research. This ideal was henceforward been emphasised in the new **Aalto University**, the merger of three different universities, Helsinki University of Technology, Helsinki School of Economics, and the University of Arts and Design. The Aalto University was established on January 1, 2010. Later on, in early 2011, the former technical faculties at TKK became Schools. With the School of Arts, Design and Architecture, and the School of Business, they currently constitute six different Schools at Aalto. Hence, I finalised this work at Aalto University School of Electrical Engineering (ELEC). Looking back, I could not have foreseen in the beginning how topical my research would become in the new university context, and how rapidly the change processes from the former TKK to the current Aalto materialised.

Thereby, I wanted in particular to study how the ideal of high-standard expertise stated in TKK's strategy was reflected in the study and career experiences. This ideal is in general related to the structural transformation of the information society (cf. Castells et al. 1999; Davis et al. 2005). Societies are confronting rapid social and technological changes, as well as globalisation. All this has an influence on an individual's expertise, and his/her competence development in working life (Rychen and Salgarnik 2003). In the 1990's, Reich divided the jobs of the future as follows (1993):

- Routine production services
- In-person services, and
- Symbolic-analytic services

Reich describes the division that "three broad categories of work are emerging, corresponding to the three different competitive positions in which Americans find themselves" (ibid. 1993, 177). Despite his local viewpoint, these categories are still valid in the current European and Finnish information society. However, globalisation impacts the location where work is

performed – engineering work can take place anywhere around the world. For instance, industrial plants and factories are changing their location, typically from European countries to the ones with lower labour costs in Asia.

Engineering is a typical example of a profession performing symbolic-analytic or knowledge-intensive work. In engineering work, developing and maintaining expertise and scientific thinking skills is particularly crucial. Reich includes in the third category "all the problem-solving, problem-identifying, and strategic-brokering activities" (1993, 177). Reich lists examples of symbolic-analytic services, a few of which are provided by engineers. He adds that in this category the manipulations of symbols are traded, for instance, data, words, and oral and visual representations. Furthermore, Reich describes that "symbolic analysts often have partners or associates rather than bosses or supervisors", and he notes that these analysts seldom proceed along well-defined paths. (ibid. 1993, 178–179.) Still, employees in symbolic-analytic jobs, for instance, engineers, often regarded as "nerds" without any social skills, are facing growing demands for social facility especially in interaction with customers and subordinates (Educating the Engineer of 2020, 2005, 10; Lappalainen 2012).

This work attempts to identify ways in which electrical engineers have faced all this development; during their studies, and especially their means of growing and developing expertise and professional competencies in working life. The particular aim of this study is **to investigate electrical engineers' experiences in their education, career, expertise, and professional competencies.** The research draws from several frameworks – institutional (a university), cognitive (engineering education), and social (learners, their educators, and other stakeholders).

This research was conducted at the former Helsinki University of Technology (TKK) at the Faculty of Electronics, Communications, and Automation in co-operation with TKK Dipoli Lifelong learning unit (currently under the name Aalto PRO) which together established doctoral school positions within the engineering education area. This study pursues both organisational and personal goals. First, the majority of engineers at TKK have not graduated in the targeted five years' time. In this study, I aimed to gain insight into the reasons that may have caused delays in electrical engineering studies. Second, I was interested in the possible differences in the expectations of various stakeholders regarding the engineering education. The university and the industry may have some tensions how the relation between engineering theory and practice in the education should be balanced. Furthermore, the gov-

ernment is also placing growing pressure on universities; the efficiency of their students and graduates' time-to-completion. This means, for instance, that universities are urged to develop sufficient study services for students. Third, I set out to investigate how an individual student perceives the process of studying, and gains skills, knowledge, and expertise in electrical engineering, and finally moves on to working life after graduation.

This work is divided into two main parts; the theoretical and the empirical parts. The theoretical part of the work deviates to some extent from the typical dissertations written in the monograph form. Because of the methodological approach adopted, I begin each chapter with an overview of prior research describing the theoretical framework. For instance, prior research on expertise is incorporated into Chapter 2.4 (Planting the seeds of expertise into higher education). This way the sections in the theoretical framework form a coherent narrative path of their own and lead readers through the work. The prior research field covering expertise, competencies, and learning would have been far too wide for this research context. The prior research principally attempts to focus on engineers, engineering students, and engineering education.

The results are documented chronologically according to the completion of the data collection phases:

1) The first internet survey for graduate engineers (n=99) in autumn 2006
2) The second internet survey (n=120) in autumn 2007
3) Twelve interviews from May 2008 till October 2008

The quantitative and qualitative results are analysed and contrasted with each other and reviewed per research questions in Chapter 5 (Summary of the results). Chapter 6 (Conclusions), provides possible solutions and proposals for actions. I also represent thoughts and ideas for further research in the field.

2 Engineering education in a larger context

The focus of this work is on higher education, especially higher education in electrical engineering. In this chapter the theoretical context is introduced: history and philosophy, academic disciplines, expertise, and competencies in relation to engineering education. I attempt to see connections and links between various stakeholders in the thesis context, for instance, how the substance of expertise and competencies are integrated in the engineering education. This chapter is divided into six different sections of which the last one summarises the various themes.

2.1 The historical and philosophical context of higher engineering education

Teaching in higher education has its underpinnings in hundreds of years of culture, philosophy, and traditions. The first European university was established in Bologna, Italy in the year 1088. By comparison, the first Finnish university was established in Turku in 1640 at the time when Finland was a part of Swedish monarchy. Helsinki University of Technology was first founded as Technical School of Helsinki in 1849, and later on, it was changed to Polytechnical School (1872) and Polytechnical Institute (1879). In 1908, it became a university-level school and was renamed as the Technological University of Finland. (Nykänen, 2008) Other technical universities in Finland were established far later, for instance, the technical universities in Tampere and Lappeenranta in the 1960's. Values that have formed technical universities and engineering education differ more or less from the ones having shaped other academic universities.

Traditionally engineering education has been developed along technological advance in society. Higher engineering education has consisted of designing and controlling machines, equipment, and processes through mathematical and scientific knowledge. Accordingly, technology has become a mirror of social development. The expansion of industrialism in the Western countries created a need for research co-operation between industry and universities. The research units at universities solved problems within the basic research and educated new researchers for the industry. First in the US and somewhat later on in Europe leading universities and universities of technology started to 'tailor' their curricula and research projects so that they met the needs of the industry. This research connection established a new type of system be-

tween the academic world and the industry. In the new system universities focused mainly on the scientific and technological basic research. The research institutes owned by the industry had their part in the research and development work, the results of which public research institutes tested and checked. (Michelsen 1999, 253–255; Jørgensen 2010, 219–225.)

The development of engineering profession in Finland has been substantially tied to the technology and large-scale industry. The co-operation of different stakeholders; engineering education together with the research and education at Helsinki University and representatives of the industry established the foundation for the modern engineering education in Finland. (Michelsen 1999, 253–255.) The common progress elsewhere in the western world may well have affected the character of engineering education at Finnish technical universities, which, in comparison with other academic disciplines, is more a combination of theory and practice.

Likewise, it is also important to consider which philosophical values have shaped engineering education. Mitcham (1994, 12–13) says that the philosophy of technology "should include two different but related kinds of reflection. It needs to be aware of its own history and able to articulate a set of systematically integrated issues." He states that without the first reflection (awareness of one's own history), the philosophy of technology is likely to ignore such issues which have happened in the past albeit they could improve the present. (ibid. 1994, 12–13.) Williams supposes that the current age is "without a sense of history", and she regards the view of history as a "pervasive" struggle between technological change and technological resistance (2002, 14-15). When assessing the current situation in engineering education, it would be necessary not to ignore the results of the past when planning the current and future education. With respect to Mitcham and Williams, I contend that philosophy and ethical values should be well integrated in the holistic thinking when designing engineering education in general.

The question has been posed whether engineering science is an applied science, or whether it is a unique scientific field. Another question concerns the dependence of engineering science upon the natural sciences. Hendricks, Jakobsen and Pedersen (2000) have discussed whether engineering sciences are utilising the results and the methods of natural sciences, or whether they have created their own methods and knowledge independent on natural sciences. They point out that engineering is a science governed by its own epistemology, methodology and ontology. Hendricks et al. (2000) completed a systematical survey of the following research profiles: 1) pure science, 2) ap-

plied science, and 3) engineering science. In their work, they refer to Kuhnian paradigm shift (Kuhn 1970) in which Kuhn claimed that science does not progress via a linear accumulation of new knowledge, but undergoes periodic revolutions, paradigm shifts. (Hendricks et al. 2000.) Concurrently, engineering as a scientific discipline in comparison with social sciences and humanities, pursues exact results in a form of figures, equations, and tables. However, current society has affected the engineering education so that also further interdisciplinary approaches are required for merging pure, scientific results with the ones in social sciences in order to achieve complex engineering knowledge. Such examples may be, for instance, sustainable development systems, and technological solutions against global warming. When studying this area not as an engineer but as an educational scientist, I perceive electrical engineering as an applied science but undoubtedly with definite needs for own educational ideologies and methodologies.

Universities have three roles: research, teaching, and support of the development of the surrounding society. Each university in its own context should recognise its special strengths and the possibilities of these roles when aiming at the overall high quality. Kogan (2000, 208) contends that universities have various institutional roles regarding the advancement of social and public policies in higher education. They have social obligations to perform; academic tasks of teaching, promoting learning and the creation and testing of knowledge, task to research, and also the so-called third task, to work with values and groups outside the university. Jørgensen (2010, 224) underlines one important historical change which emphasised the research task of the universities. The increase in public and military funding of engineering education during World War II caused the development of science base of engineering. From the outset, there had been a gap in engineering curricula between the science based and more applied subjects, and the historical change, or transition diminished the controversies. (ibid. 2010, 224.)

The role of the research task has mainly been stronger at higher engineering universities. However, technical universities in Finland have also recently emphasised the third task, societal, next to research and teaching. The societal, third task includes the notion of serving the surrounding society. Bowden and Marton (1998) refer to the third task as “being oriented to, co-operating with and service the society of which the university is a part.” This should affect the basic engineering education and also continuing education in engineering, bringing the society-related aspects more to the front. Finnish Universities Act (645/1997 in English, Section 4, in part 1, and Amendment 715/2004) defines the third mission of universities as follows: “in carrying

out their mission, the universities shall interact with the surrounding society and promote the societal impact of research findings and artistic activities". However, this question has raised disagreement, for instance, on the roles and distribution of work which university unit owns the responsibility on continuing engineering education, Schools or special units for continuing education. The university faculties may have sometimes been resistant to organise it. Furthermore, they might have perceived the question of arranging it with more narrow means, for instance, additional courses for graduate engineers in working life.

Concerning the philosophical values by Mitcham (1994), it is interesting to connect them with the thoughts of José Ortega y Gasset. In his work Meditación de la técnica (Meditation on Technics 1939 cited in Mitcham 1994), he claims that *"technics is necessarily involved with what is to be human"*. Ortega describes human nature in relation to technics as follows: "*First, there is the creative imagination of a project or attitude toward the world that the person desires to realize. Second, there is the material realization of that project, since once we have imagined what we want to become, what we want to make ourselves--there are certain technical requirements for its realization. And of course, because these requirements will differ according to the project to be realized—there are as many different kinds of technics as there are human projects*." Ortega's thoughts form the dimensions for the aims of higher education, in this context especially for engineering education. Taken together, engineers require both imagination, and abilities to creatively meet certain technical requirements in completing projects.

Overall, the third task ought to be seen holistically. Universities at large are responsible for the higher education which produces experts serving the human society nationally and globally. However, simultaneously the task must be considered from the single student's point of view: the individual chooses to study a certain field in order to become an expert, and the time of his/her studies is a unique and subjective experience. In this study, this means, for instance, becoming an engineer and forming an engineering identity.

I examined the Strategy document of Aalto University document (Aalto University strategy 2012) both from the viewpoint of individual student, and the learning community. Despite the different time period of studies of my sample groups in the study, I explored the strategy of the current university because the results may affect on-going engineering education. The strategy constitutes the foundation for various curricula at the university, and it covers the tasks given to the universities. Because Aalto University is a merger

of three different universities and also represents different academic disciplines, the strategy cannot merely concentrate on engineering education. Thus, the main theme in the Aalto strategy is the quality of the entire functions at the university. One of the missions included in the strategy is that Aalto University educates experts who are "responsible, broad-minded", and who can "act as society's visionaries and change agents". Turning to the education and learning context in the document, learning-centred culture is emphasised as well as the development of educational methods. In consequence, the strategy encourages teachers at Aalto University to take "initiatives towards better teaching approaches and methodologies". The third, societal task, in turn, will be enabled with "systematic and inspiring dialogue" between the university and the stakeholders. (Aalto University strategy 2012.) Developing the evaluation criteria for measuring the quality of good education offers a constant challenge for Aalto.

As stated in the Aalto University strategy, the university's role as a producer of new knowledge has been emphasised. Moreover, it is due to the economic development based on expertise and competence, environmental changes, globalisation, and rapid development of technology. On the other hand, there is also criticism on the increased role of the state and employers in the determination of the higher education curriculum (cf. Dunne, Bennett and Carré 2000, 105). Furthermore, in regard to engineering education in Finland, in some connections graduate engineers are referred as 'outcomes' or 'results' of the education. In Finland, it is not rare that students are seen as figures; such as annual student graduation rates by universities. For instance, the Finnish Ministry of Education and Culture regularly calculates the costs of each academic degree for the society, and measures the effectiveness of various degree programmes (cf. KOTA online service on statistics). Overall, including these, they serve as indicators of effectiveness in higher education.

2.2 Disciplinary cultures with respect to engineering education

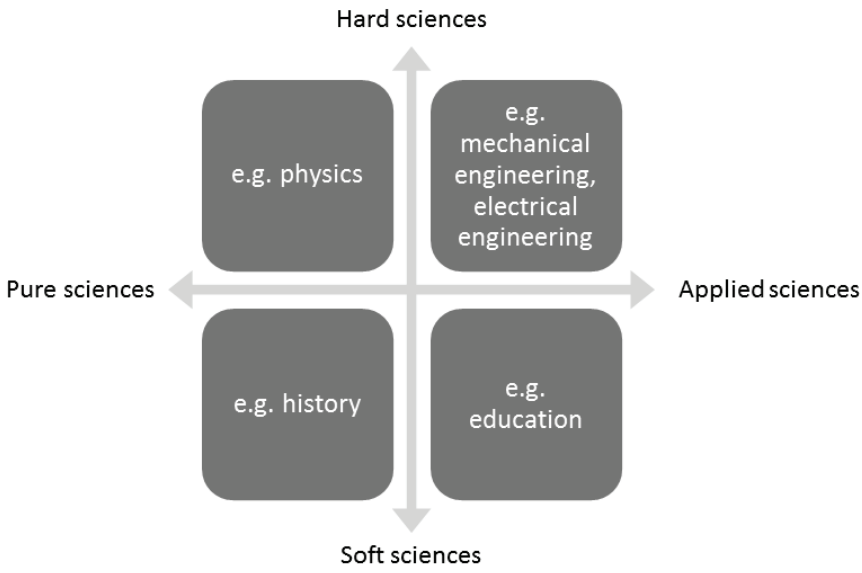
Besides academic cultures, disciplinary contexts in academic world have also been formed during centuries. Biglan (1973a, 1973b) originally developed the grouping of academic disciplines. He studied relationships between the characteristics of academic subject matters and the structure and output of university departments. His results were based on questionnaire data from academics with a sample of US faculty members (n=168 from University of Illinois and n=54 at a small Western college). Biglan could derive three main dimensions in his study: hard versus soft, pure versus applied, and life system versus non-life system. (ibid. 1973a; 1973b.)

Later on, Kolb (1981) wrote about "the commonly accepted division of academic fields into two camps, the scientific and artistic, or abstract and concrete". Kolb's work has likely been affected by the thoughts by Snow (1959), in which he argued that the breakdown of communication between the "two cultures" of modern society – the sciences and the humanities – was a major obstacle of solving world's problems. Kolb (1981) describes a two-dimensional space from which a four-fold typology of disciplinary emerges. He continues that in the abstract reflective (hard pure) quadrant are clustered the mathematics and natural sciences, while the abstract-active (hard applied) quadrant includes science-based professions, most particularly the engineering fields. The third quadrant, concrete-active (soft applied) consists of social professions as education, social work, and law. The fourth quadrant according to Kolb (soft pure) includes the humanities and social sciences. Each university can be regarded as an academic community, and it consists of academics in working in different subject areas. According to Kogan (2000), development at universities has to be rooted well enough "into the intellectual self-confidence of the disciplines and subject areas of the academics".

Becher and Trowler (2001) extended Kolb's thoughts on disciplinary groupings of the nature of knowledge. In the first edition of the book Academic Tribes and Territories (1989), Becher mentions that the book started with an obsession due to his own irritation towards Snow and his thoughts about the aforementioned two cultures. He has a view that Snow offered "a superficial and conceptually flawed polarization" between the two worlds. In general, Becher and Trowler describe the relationship between the distinctive cultures within academic communities (academic tribes and academic ideas) in their work. For them, cultures are "sets of taken-for-granted values, attitudes and ways of behaving, which are articulated through and reinforced by recurrent

practices among a group of people in a given context" (ibid. 2001, 23). They claim that the concept of an academic discipline is on the whole complicated. They conclude that disciplines are in part identified by the existence of relevant departments. However, it is not self-evident that each department represents a discipline. Their results, disciplinary groupings (see Figure 1), were based on the qualitative data collected in interviews in the US and in the UK. (Becher and Trowler 2001, 41.)

Figure 1. *Examples of disciplines by disciplinary grouping (according to Kolb 1981, Becher 1994, and Becher and Trowler 2001)*



These disciplines have also affected the teaching and learning at university level and created specific traditions. In the grouping (Becher and Trowler 2001), engineering is placed in the 'hard-applied' disciplinary grouping. However, the education in particular in electrical engineering is to a large extent based on physics, which is located as a 'hard-pure' discipline.

Neumann, Parry and Becher (2002) provided a conceptual analysis on teaching and learning in their disciplinary contexts at their universities in Australia and in the UK. In their study, they focused on undergraduate teaching and learning. Although their views are presented from another, Anglo-Saxon cultural viewpoint, they can well be examined in the Finnish context. They explored different aspects of the domain of teaching and learning, and highlighted the contrasts between such aspects within the four disciplinary groupings. According to Neumann et al. (2002), hard pure knowledge is typi-

fied as having a cumulative, atomistic structure, concerned with universals, simplification and a quantitative emphasis. Conversely, soft pure knowledge is reiterative, holistic, concerned with particulars and having a qualitative bias. In their study, Neumann et al. listed the aspects of teaching and learning by dividing them to knowledge related such as curriculum, assessment and main cognitive purpose, and to socially related, for instance, the group characteristics of teachers, the types of teaching method involved, and the learning requirements of students.

In hard pure disciplines, the curriculum has a cumulative, atomistic nature in contrast to the reiterative and holistic nature within soft pure disciplines. According to Neumann et al. (2002), hard pure curriculum is inclined to be regarded as linear and hierarchical, building increasingly towards existing knowledge. On the contrary, in soft pure disciplines knowledge can be described with increasing levels of subtlety and insight into previously familiar areas of substance. The content in hard pure disciplines is generally predetermined, cumulative, and quantitatively measured. The teaching and learning activities are focused, instructive, and teacher-focused. Stereotypically, in teacher-focused learning, teachers 'pour' the knowledge into the minds of students who mainly stay passive in the learning process. Conversely, in soft pure domains, knowledge is built in a formative process. Furthermore, the content is likely to be "more qualitative and free-ranging", when teaching and learning activities are "interpretative and constructive". According to the writers, hard applied domains, for instance, in engineering, would call for progressive mastery of techniques in a linear sequence, which has the foundation in "factual understanding". Mathematical and theoretical subjects like the courses in circuit analysis and electromagnetic field theories are typical examples of this. Respectively, in soft applied domains, Neumann et al. state that the knowledge is accumulating in a reiterative process. (ibid. 2002, 407–408.) When observing the Finnish system, the situation is not as black-and-white as the writers claim. Laboratory works and exercises form a good part of the courses in engineering education, and mathematical knowledge is built partly by successive, reiterative exercises until students attain more extensive understanding.

Assessment is another knowledge related aspect as stated by Neumann et al. (2002). In hard pure domains there is an apparent tendency to prefer specific and closely focused examination questions to broader, essay-type assignments. Furthermore, in hard pure disciplines due to the quantitative nature of knowledge, numerical calculations are most often used. Students in soft pure disciplines are more often assessed with essays, project work, and

reports to indicate their level of understanding of a complex qualitative domain. (ibid. 2002, 408–409.) In hard applied domains, also laboratory work and programming tasks and to some extent group work are used as a way to assess the students. Neumann et al. (2002) state that according to their experience, a larger part in hard applied than in hard pure subjects is committed to the solving of problems, which is rather obvious in engineering education. Furthermore, they carry on that also in soft applied fields, problem-solving is emphasised.

When the focus is on group characteristics of teachers, it may be noted that academics in hard pure fields in general are more committed to research than to teaching. The situation in hard applied fields is somewhat comparable. (Neumann et al. 2002) According to author's experience, at Aalto University and former TKK, the research in general has been more appreciated than teaching. It is more straightforward to measure the results in research (number of dissertations, journal articles published, or their citation indices) rather than measuring how students learn, or the substance taught was comprehended. Still, teachers have been committed in teaching tasks in spite of the possible lack of appreciation. However, a Norwegian study (Smeby 1996) showed significant field differences in the time spent on teaching and preparation, as well as differences in the distribution of time between types of teaching and teaching levels. In his study, Smeby also stated that "the differences of time spent on different types of instruction are mostly due to the communication language". In this context, he describes that communication language in disciplines is more or less codified; there is a distinction between 'codified' and 'literary' fields. For instance, a heavy use of mathematics is typically connected with codified fields. Zuckermann and Merton state that various sciences and their sub-fields differ from each other in the extent to which they are codified (1973).

Conversely, in literary fields, research is commonly reported in a more essay-type form and the codes are more implicit. Smeby's (1996) studies at four Norwegian universities claimed that in comparison with academics in the other disciplinary groups, the ones in hard applied fields (for example engineering) spent the least amount of time on teaching preparation. (ibid. 1996.) The Norwegian results resemble relatively the situation at former TKK. There may be various reasons for not having sufficient time for teaching preparation and for the teaching in general. These are, for example, too much work load on teachers, the question of tacit share of respect between teaching and research, or a very high number in teacher-student relation. This all together may lead, for instance, to the lack of motivation when preparing one's own

teaching, or for instance not having sufficient time when assessing different type of tasks completed by the students.

Regarding various types of teaching methods in academic disciplines, courses in hard pure fields in general are based on large group lectures, supplemented by exercises and class laboratory sessions whereas teaching in soft pure fields is organised in smaller, face-to-face groups (Neumann et al. 2002) The particular situation at Aalto University Schools is steadily changing. Since the year 2000, teachers at former TKK could participate into pedagogical teaching training courses in which various, alternative teaching methods, for instance, problem-based learning, were promoted and practiced. The cumulative number of teachers at former TKK who completed University Pedagogical Training (YOOP) was 213 by the year 2009. These teachers rather evenly represented all the faculties and departments at TKK. (cf. Clavert 2010, 20–21) During the years 2008 and 2009, the faculties had a recommendation to have a minimum amount of teachers participating in the YOOP-training. For example, in year 2009, the minimum quota per each faculty was four teachers. The number of Aalto ELEC teachers having participated in the pedagogical training between 1999-2012 was altogether 106. The pedagogical training for teaching personnel at Aalto University seeks new ways of functions, and new pedagogical programmes were designed and launched during the years 2011 and 2012. Furthermore, the training will be more closely incorporated in the tenure track systems of professors and teachers, and correspondingly, to the functions and the substance of different Aalto Schools.

The third, socially related aspect in teaching and learning listed by Neumann et al. (2002) was the learning requirements of students. The writers assert that in hard pure fields, it is needed to possess skills in solving problems and deploying facts and figures rather than writing prose and essays. Furthermore, they continue that in hard applied fields as engineering, students are expected to possess a good memory and a competence in problem-solving. They emphasise that in the hard applied fields, practical competencies are stressed, and students need an ability to apply theoretical ideas to professional contexts. In electrical engineering, the focus of this study, students need conceptual understanding and in particular practical skills in order to solve mathematical problems. Some of the challenging topics in learning in electrical engineering are, for instance, electromagnetics and circuit analysis, which have a very theoretical and abstract substance, in comparison with the subjects in electronic engineering at large. (Keltikangas and Wallén 2010; Leppävirta, Kettunen and Sihvola 2011.)

Lindblom-Ylänne, Trigwell, Nevgi and Ashwin (2006) studied how discipline and teaching context were affecting approaches to teaching among Finnish and British university teachers (n=340). As indicated by their results, there was variation in student- and teacher-focused approaches across disciplines and across teaching contexts. They assert that there was evidence that approaches to teaching was related to teachers' discipline. Teachers from hard disciplines were more likely to have a more teacher-focused approach whereas conversely teacher in soft domains had more student-focused approaches. (Lindblom-Ylänne et al. 2006.)

A Finnish study was conducted at University of Tampere in the end of the 1990's by Ylijoki (1998; 2000). She studied university teaching and studying at university through tribe and story metaphors. She described that subjects or domains which students choose at university are being perceived as academic tribes with their own aims, traditions, values, beliefs, problems, and ways to function. She claims that studying is not only about learning cognitive fundamentals of one's own discipline, but it also means that students build their own identity during the studies. One of her results was that academic subjects or disciplines can most clearly be distinguished from each other by the professional orientation of the subject. (ibid. 1998; 2000.) Engineering science education produces graduates who have studied at an engineering community; they have shared same values and activities which have probably shaped their professional identity and thinking (Du 2006; Keltikangas and Martinsuo 2009).

Academic disciplines are linked to the culture at the universities as well. With regard to engineering education, Godfrey (2009) states that "a very high proportion of engineering educators do not share the familiarity and understanding of social scientists around the concept of culture". Furthermore, she adds that "it has merely been in the last 10 years that the terms 'culture' and 'cultural change' have gradually entered the engineering education discourse and literature". Referring to changes, she mentions that engineering educators should consider more such values, beliefs, and assumptions that have developed the culture as it is now. Godfrey explored culture of engineering education in Australia with an ethnographic case study approach. (ibid, 2009.) Later on, she enlarged the research and collected more data with mixed methods at a large university in New Zealand (Godfrey and Parker 2010).

Based on the research data, she proposed six dimensions in the culture of engineering education (see Table 1). After having completed the study in New Zealand (Godfrey and Parker 2010), the titles of the dimensions were somewhat altered. However, the content in them stayed by and large the same.

Engineering Way of Thinking	What constitutes a reality, in particular at an engineering university? What type of knowledge is valued? Perception of truth? Is there a predominant way of thinking?
Relationship to Environment	What is the relationship of the culture of engineering to the rest of the university and academia in general, the profession and community?
The Engineering Way of Doing	Is there a *"right"* way to teach or learn? What is the primary task of a School of Engineering? How is it to be accomplished?
Relationships	The nature of relationships in the culture? Is there a *"right"* way for people in this culture to relate to one another? The relationship between personnel and students, how is it working?
The Engineering Identity/Being an Engineer	Are there attributes and qualities essential in being "an engineer", in particular academic? Who can fit in and be successful?
Homogeneity/Acceptance of Difference	How is difference accepted? Is it as desirable or necessary to have homogeneity or diversity in the members of the culture? Is there tension between educational beliefs and attitudes?

Table 1. *The proposal of six dimensions in the culture of engineering education (Godfrey 2009, 9-10, Godfrey and Parker 2010)*

Each dimension was formed on beliefs and assumptions on values and cultural norms apparent at the institution in which the data were collected. The content of each dimension is exhibited in the Table 1. Godfrey and Parker (ibid. 2010) stated that universities in general have identified a common

question “to know where we are” in order to find their ways “where they want to go”. The understanding of how culture at a university, or in one of its schools is formed will help to achieve the set targets.

When considering this study, a very stimulating question is how these dimensions interrelate with the education and learning at TKK, and how expertise and professional competencies are located in our cultural context. My expectation on the qualitative part of the study was that the narrative stories of the engineers will tangle also the culture in engineering education, and, for instance, how the identities of the interviewees have developed during their career. In this study, the focus has mainly been on their identity development in working life.

With regard to the culture in engineering education, another investigation (Stevens et al. 2008) in the US developed a framework with three different dimensions for understanding the process of “becoming an engineer”. Their dimensions were: disciplinary knowledge, identification, and navigation. The dimensions were based on an ethnographic, four-year study of US engineering students. The first one is associated with the concept of learning, and with the expert-novice paradigm. Their key finding was the question of what is accountable, engineering knowledge. Their second dimension, identification, points how a person identifies with engineering and is identified by others as an engineer. The third one has a focus on how a person moves along the institutional and personal paths; becomes institutionally identified as an engineer. Different students navigate in a different way through their path of engineering studies. Differences may be consequential not solely where students end up in the working life, but in addition for the duration of their undergraduate experience, the social networks they build, and the quality and substance of their identification with engineering. (Stevens et al. 2008, 355–357.)

This work is focused on electrical engineers and their career paths, in particular how their paths are related to expertise and professional competencies. The data gathered for the study consist of perceptions both in quantitative and qualitative form. Their perceptions interrelate with the academic culture in engineering in practice. In the research, both graduate and electrical engineering students with delayed studies were examined with two Internet surveys and qualitative, narrative stories, “work-history narratives” (Mischler 1995).

On the whole, there is a worldwide concern on the competiveness of the national economies in the current information society; especially US literature on engineering education bases the needs for developing the education on the national advantage (Educating the Engineer of 2020, 2005; Rover 2008; Gereffi et al. 2008). In this study, I attempt to see students from various viewpoints. Regarding engineering education and students as its targets or outcomes, there are various options. First, engineering students are regarded as learners at a university. Simultaneously, they are individuals as well as becoming members of various communities. Thirdly, each nation regards them as a becoming, productive labour force.

Disciplinary cultures do not form the main approach in this study but primarily support and give direction to the implementation to it. Furthermore, disciplinary culture in electrical engineering merely composes a part of the larger unity. In the next section I continue with a more detailed level; on professional competencies. The scope of this study has been narrowed to review the prior research from the standpoint of engineering education.

2.3 Competencies – requirements in engineering?

As to the context of this research, there is a connection between competencies, universities, and working life. Technical universities are educating engineers who face the increased pressure and demands of the working life and the society around us. Also, educators in higher engineering and at universities in general, confront demands coming from the industry and working life. Electrical engineers are so called 'outcomes' of the education; which competencies the society is expecting from them (Bowden and Marton 1998). The CDIO initiative (Conceive-Design-Implement-Operate) in engineering has particularly enhanced the development of engineering programmes. The initiative emphasises that universities should educate "successful engineers". (Crawley et al. 2010, 1-4). On one hand, the present study did not examine the research completed within CDIO initiative due to the vast number of them. On the other hand, this study had a restricted focus on the electrical engineering education.

From the educational point of view, it is meaningful to teach such substance to the engineering students they would most likely require in their career. But they also require such knowledge, skills, and competencies which may seem to appear unnecessary, or even uninteresting. Bowden and Marton emphasise that it is essential to remember that the curriculum for any university "needs

to be developed around the idea that students are being prepared for a future which is largely unknown" (1998, 94). They carry on with a very simple recommendation for university teachers: "If you do not know what the future situation will be, then teach students some fundamental skills which they can apply to any situation" (ibid. 1998, 94–95). Similarly, an Australian study (Scott and Yates 2002, 372) stated that the "total university experience" helps to develop needed capabilities. This is very much factual now in the 2010's when the pace of technological change in society is becoming increasingly rapid.

The concept of competence has its origin to back to Persian, Greek, and Roman times. It has been used in Europe from the sixteenth century and entered professional literature in public administration, organisational structure, law, management, and education and training in the 1970's (Mulder 2007 cited in Mulder et al. 2009). According to Mulder et al. (ibid. 2009), competence can be understood as a series of integrated capabilities. These consist of clusters of attitudes, skills, and knowledge as necessary conditionals for performing tasks and solving problems. It can be also an ability to function efficiently in a certain profession, work, role, organisation, or situation. It can either be behaviour-oriented, or task-oriented. Furthermore, competencies may merely receive meaning in a particular context and when they are adequately specified. (ibid. 2009.)

In this study, the word competence (plural competencies) is used according to Lemaitre et al. (2006) whose semantic analysis was aiming to cover the different interpretations of the "notion of competence". According to the writers, competencies put across knowledge in action or knowledge performed. They also argue that the word competence always represents a value judgement. Furthermore, there are several phenomena driving to promote a discourse on skills and competencies. The current world, in which graduate engineers start their career paths, is increasingly a service-based economy which modifies engineers' professional knowledge. They do not need just technical knowledge but also non-technical, in particular, social skills. Moreover, Lemaitre et al. claim that engineering activities are becoming socio-technical in nature, requiring knowledge which goes beyond the ability to handle technical and scientific tools. (ibid. 2006.) Expectations are quite similar with respect to Reich's (1993) thoughts what people in symbolic-analytic services perform and what they in particular need.

Competency-based education programmes were first introduced in the US. Such programmes were initially established in teacher education in the late

1960's, and in the 1970's, they progressed through applications to other professional education programmes in the US. With respect to the curriculum design, the basic idea with the competency-based approach is to define skills graduates need in working life, and then design curriculum that covers the defined needs. In Europe, competency-based approaches were first introduced in vocational training programmes in the UK and in Germany in the 1980's. In Australia, they were first presented in vocational training and professional skills credit in the 1990's. (Bowden and Marton 1998, 98–99; Mulder et al. 2009.) The roots of this approach can be found in the thinking of educators such as Bloom. It values the tendency for reliability of observation and judgement. This can be seen, for instance, in Bloom's taxonomy where in course descriptions educational objectives are delineated with certain verbs such as 'list', 'state', or 'recognise' which mainly describe student behaviour. (Bloom 1971 cited in Bowden and Marton 1998). Then and later, the taxonomy was, however, much criticised because of the narrowness of such approaches (Bowden and Marton 1998, 99). Nevertheless, educational objectives in curriculum design should include a notion how students understand and internalise competencies integrated in education.

OECD (Organisation for Economic Co-operation and Development) launched in 1997 a programme on defining key competencies for the knowledge society. The aim of the programme (Definition and Selection of Competencies: Theoretical and Conceptual Foundations, DeSeCo) was to define broader categories for competencies which are needed in the knowledge economy, or in the information society. The programme took a larger view than education or working life, i.e. their main activity was the identification of theory-grounded sets of key competencies from various disciplinary perspectives; anthropology, psychology, economics, sociology, and philosophy. Based on the programme work, a three-fold categorisation of key competencies was constructed: acting autonomously, using tools interactively, and functioning in socially heterogeneous groups. In the programme results it was particularly emphasised that key competencies are interrelated, and they are developed through action and interaction in formal and informal education. (Rychen and Salgarnik 2003.)

In terms of the university education, there have been several surveys by governments and employer associations where the need to learn generic skills has been mentioned. They usually tend to consist of skills in problem-solving, communication, and teamwork. Competence, in general, may be defined in diverse ways depending on the discipline. It can refer both to the requirements of the work situation and to a person's knowledge, skills and abil-

ities, based not only on cognitive factors, but also on non-cognitive factors, for instance, self-confidence and motivation (Ellström 1997). It can be stated that competence is related to ability to apply knowledge. With respect to academic graduates and their general competencies and skills, Biggs and Tang (2007, 65) list such qualities as critical thinking, ethical practice, creativity, teamwork, communication skills, and lifelong learning. These qualities listed are rather similar to the findings in the DeSeCo programme (Rychen and Salgarnik 2003).

In the prior research, Lemaitre et al. (2006) have investigated what type of competencies, skills, or capabilities are needed in different engineering professions, i.e. professional competence. Engineering graduates need to have technical as well as emotional intelligence (Scott and Yates 2002), in addition to the competence in both science and practice of engineering (Martin et al. 2005). This division of engineering competencies is another way of viewing them – the science of engineering and the practice of engineering. The science of engineering is the set of mathematical and scientific tools used to solve engineering problems. The practice of engineering, on the other hand, may be defined as the recognition and formulation of a problem and its solution. (Martin et al. 2005) Overall, competencies achieved during engineering education and later in working life, can be divided into key technical and non-technical competencies (Meier et al. 2000; de Graaff and Ravesteijn 2001).

Universities define as well what competencies and skills students should have when graduating. For instance, the study programme in Electrical Engineering at Aalto describes that

> "the aim of the higher basic university degree in electronics and electrical engineering is to provide a theoretical foundation and practical knowledge and skills to apply in such tasks which require problem-solving skills and independent solutions in technology, technology applications, or in production. It also aims to provide profound competencies in performing demanding tasks in one of the earlier mentioned fields. As a professional aim, the degree pursues in offering possibilities in deep interdisciplinary utilisation of electronics and electrical engineering. The scientific goal is to give strong knowledge in electronics and electrical engineering based on scientific foundation as well to independently acquire scientific knowledge. Furthermore, another scientific target is to give competence and skills in expert tasks, postgraduate studies and research work." (Writer's own translation from Aalto ELEC internet pages)

Inferring to these attributes, competencies and skills of the degree programme are defined in a rather general level.

A study among the US engineers was conducted on how an engineering profile is built up. The outcomes demonstrated that 100 engineers, both academic and non-academic, gave high importance to the following attributes: technical competence, communication, profound thinking, solution orientation, professionalism, and client orientation. In these outcomes, continuous learning was ranked lower as the aforementioned. The authors also developed a behaviour-based profile aligned with ten roles important to engineering practice. These roles draw from technical, interpersonal, and professional behaviours desired in engineers. The technical roles were: analyst, problem solver, designer, and researcher. In addition, the interpersonal roles were: communicator, collaborator, and leader. Finally, the professional roles were self-grower, achiever, and practitioner. These roles were based on inputs from diverse industry and academic views. (Davis et al. 2005.)

Furthermore, other US studies in similar area have also been conducted within CAEE (Center for the Advancement of Engineering) funded by NSF (National Science Foundation). For instance, APS study (Academics Pathway Study) was performed. One of the aims of APS was to broaden the understanding of development of engineering skills, and identities. It had several sub-studies in which two instruments were emerged; PIE (Persistence in Engineering) and APPLES (Academic Pathways of People Learning Engineering Survey). APS focused on the following research questions and areas:

- How do students' engineering skills and knowledge develop or change over time?
- How do students become engineers, or receive the identity of an engineer?
- Which elements in the given education contribute to the changes observed? What is difficult for students and how do they manage with possible difficulties?

The PIE-study was conducted as a quantitative, longitudinal study with surveys. It had a sample of 160 students at four universities in the US from 2003 to 2007. It was followed with APPLES1 and APPLES2 studies; approximately 900 students were participating in the same institutes as PIE-study had. Furthermore, APPLES2 was conducted with a selected, stratified sample of 21 universities in the US (Sheppard et al. 2010). These studies had, for instance, questions on students' persistence and motivation, importance of skills taught in the education and students' confidence in their skills, and academic engagement and experiences. In brief, all these three studies shared the same survey instruments: a common set of variables which represented

the key concepts that researchers had proposed to influence undergraduate's persistence in the engineering major. The areas of key concepts were skills, identity, education, and workplace.

US researchers as a part of CAEE have as well studied engineering students' transition from the university to working life. For instance, Korte, Sheppard and Jordan (2008) completed a qualitative study on early work experiences of US graduates in engineering. Their findings showed that the social context in the workplace is a major drive of engineering work. Furthermore, they stated that engineering programmes should better prepare students for the social context of their work. Likewise, organisations, where graduates go to work, should manage the social context of the working group to help newcomers better integrate into their systems.

Various research studies on engineers and other graduates from higher education in Sweden have been completed during the last decade. Nilsson (2007) presented a comparative study of physicians' and engineers' learning and competence use at University of Linköping in Sweden. Nilsson focused on describing and analysing recently graduated physicians' and engineers' experiences of the relationship between the professional education programmes and the respective professional practices. Nilsson completed a qualitative study with altogether 43 interviews with graduated students. His results showed that theory and practice were intimately integrated in the physicians' professional education, while the engineers' experiences of the educational programme were characterised by little overlap between the theory and practice. Furthermore, both physicians and engineers regarded education as constituting a significant credential to practice their profession while engineers also thought that it increases individual employability. (ibid. 2007.)

Yet, an alternative study from Linköping University in Sweden (Axelsson 2008) examined formation of knowledge and professional identification through physicians' and engineers' education and work. The aim of the study was also to describe and interpret the relation between higher education and work. The study was a qualitative one based on text analysis and interviews of physicians and engineers. One of her results was that becoming an engineer or a physician means significantly different processes. The engineers in information technology were becoming generalists in comparison with physicists. At work, engineers were using their title "as a flexible strategy" and their identification was restricted to place of work, occupation, and working hours. By contrast, the physicians' identification of their profession was a fixed state of mind; their profession was strongly tied to their personality.

Overall, the results stated that both engineers' and physicians' career paths may be characterised "by life-long qualification". (ibid. 2008.)

Studies of this type in the Finnish engineering education field are still rare. Lepistö-Johansson (2009) studied more this area specifically from a gender point of view. Her dissertation study of women managers' identities construction was completed at Lappeenranta University of Technology. She as well collected qualitative interviews (13 women managers) which she analysed with a qualitative discourse analysis approach. Her finding was that the gender (being a female manager) became highly visible in managerial contexts when it was used for specific purpose, for instance, treated as a strategy. The female managers understood its meaning in different ways, and overall divided into positive or negative understandings. (Lepistö-Johansson 2009.)

When thinking about competencies in a larger scale in Finland, there have been successive CPD (Continuing Professional Study) reports published by The Finnish Association for Graduate Engineers TEK. They have followed the professional development of its members by quantitative surveys in which for various age cohorts have completed a large survey questionnaire on professional development. One of their research studies (Savolainen 2010) was based on the data collected with a survey (n=1215) and thematical interviews (20 respondents). The survey respondents consisted of four different age groups (32 years, 40 years, 50 years and 58 years old) who were working as experts, senior experts, managers, or in top manager positions depending on their work experience. The results showed that competence and its development needs should be discussed in working life with employers in concrete terms. Regarding the challenge of being and becoming an engineer in the current society, the results emphasised that learning in the workplace is the pivotal means of developing one's professional skills and competence. With respect to university education, the results provide evidence that the seeds for learning to learn should already be integrated in the engineering education.

This section has examined competence and professional competencies how they are usually defined, in particular from engineers' viewpoint. Regardless of which research to refer in this context, same types of engineering skills tend to be important and needed in working life. With respect to the education and curriculum design, I may suggest that the two distinctive areas; the science of engineering and the practice of engineering (Martin et al. 2005) should be in proper balance in the curriculum design.

In the next section I move on to examine expertise, in particular from the standpoint of engineering education. As the field of theories on expertise is very large, I continue as focused particularly in the engineering context.

2.4 Planting the seeds of expertise into higher engineering education

One of the aims of engineering education is that an individual grows towards expertise during the time of studies, and becomes gradually an expert in one's own domain when gaining practice and knowledge in working life. Expertise has a variety of definitions, which are rather much connected to a certain context. One encyclopaedia describes an expert as "someone who has a special skill or special knowledge of a subject, gained as a result of training or experience" (Longman Dictionary of Contemporary English 2006, 548). According to Boshuizen, Bromme and Gruber (2004), experts can also be defined "as top performers who excel in a particular field", or "professionals who achieve at least a moderate degree of success in their occupation".

There has been a particular interest in the superior knowledge that experts have in their domain of expertise since the beginning of Western civilisation. The special status of the knowledge of experts in their domain of expertise is acknowledged even as far back as the Greek civilisation. Some examples from history describe how expertise was formed and built up. During the Middle Ages, craftsmen formed guilds to protect themselves from competition. They passed on their special knowledge to their students, the apprentices. When the knowledge and expertise of the apprentices grew, they themselves became Masters, and were responsible of the quality of their special domain. Further on, being Masters themselves, they started to teach new apprentices. (Ericsson 2006). In a comparable manner, the academic world was established in the twelfth and thirteenth century as "a universitas magistribus et pupillorum", or "guild of masters and students". Influenced by the University of Paris, most universities in Europe conducted all instruction in Latin, where students were first apprenticed as "arts students", then completed the preparatory programme, and after that were admitted to the more advanced programmes in theology, law, or medicine. In order to become a master, the advanced students needed to satisfy "a committee of examiners, then publicly defending a thesis, often in the town square and with local grocers and shoemakers asking questions". The aim of the universities was to accumulate and explain knowledge, and in the process masters organised the existing knowledge. (Krause 1996 cited in Ericsson 2006, 5.)

Expertise, in general, refers to the characteristics, skills, and knowledge that distinguish experts from novices and less experienced people (Ericsson 2006). Expertise has usually been defined as the ability to successfully execute problem-solving tasks related to one's professional field (Ropo 2004). Furthermore, he adds that "experts seem to possess better-organised and more specific knowledge structures that they can access almost intuitively in the problem situations".

Bereiter and Scardamalia (1993, 6) claim that "expertise is easiest to identify when it differs most dramatically from what ordinary people can do". They continue that expertise consists of procedural knowledge (skills) and formal knowledge which in this context means higher engineering education. Furthermore, it is partly informal knowledge, which is the expert's elaborated and specialised form of common sense. Bereiter and Scardamalia also state that expertise includes impressionistic knowledge, which could be called in other words 'intuition' or 'instinct', and it is experienced as feeling rather than knowing. They carry on that the normal process of learning forms the foundation of expertise, but according to them that is not what makes expertise distinctive. They claim that "expertise is distinguished by what people do over and above this normal process", and they assume that the process of expertise is the process of tackling problems at higher and higher levels which Bereiter and Scardamalia refer as "progressive problem solving". (ibid. 1993, 96–98.)

Dreyfus and Dreyfus (1986) have described the process of becoming expert as a progression from "analytical knowing what to do involved know-how" through five sequential phases (see Table 2). They studied the skill-acquisition process of airplane pilots, chess players, automobile drivers, and adult-learners of a second language. They observed a common pattern in all cases, which they called "five stages of skill acquisition" (ibid. 1986, 19). Dreyfus and Dreyfus claim that they refer to "stages" for two main reasons. First, they state that each individual, when confronting a certain type of situation in his/her skill domain, will typically approach it first in the manner of the novice, then of the advanced beginner, and so on through the five stages. Second, according to them, the most talented individuals are able to employ the type of thinking higher even than the most talented individuals at an earlier stage in their model. In a novice stage, a person relatively blindly follows limited rules. At the second, s/he already has reached a stage of more flexible and situationally sensitive rule use. At the third, "competence" stage, a person applies goal-directed plans and strategies. At the fourth, "proficient" stage, the becoming expert has accumulated enough experience that s/he can often

recognise what is needed to be accomplished and thus has fewer needs of planning and problem-solving. At the fifth and the final stage, the person has become an "expert" – decision making becomes unnecessary, and s/he does the right issues without having to think about it.

Skill level	***Components***	***Perspective***	***Decision***	***Commitment***
1. Novice	Context-free	None	Analytical	Detached
2. Advanced beginner	Context-free and situational	None	Analytical	Detached
3. Competent	Context-free and situational	Chosen	Analytical	Detached understanding and deciding. Involved in outcome
4. Proficient	Context-free	Experienced	Analytical	Involved understanding. Detached deciding
5. Expert	Context-free and situational	Experienced	Intuitive	Involved

Table 2. *Five stages of skill acquisition (Dreyfus and Dreyfus 1986, 50)*

The nature of expertise has been studied in two general ways (Chi 2006, 21). Firstly, one way has been a study of truly exceptional people with the aim of understanding how they perform in their domain of expertise. Chi calls the first way as the "absolute approach". She claims that this type of work in psychology is called the study of exceptional or absolute expertise. The other general way, the relative approach, is to study experts in comparison with novices. It is based on the assumption that the expertise is a level of proficiency that novices can achieve. Chi stresses that "the aim of studying relative expertise is not only to describe and identify the ways in which experts excel". Rather, it is important to understand how experts became that way so that others can learn to become more skilled and knowledgeable. (ibid. 2006.) At the university context, the relative approach may be interpreted that in the curriculum design, educators should be more interested in how less skilled or less talented students could be supported to become their own type of experts after having graduated from the faculty.

The beginning of research on the nature of expertise can be traced to the 1960's, when De Groot (1966) studied the playing skills of chess masters and their information processing during a game. A variety of fields in expertise has been researched since the 1960's, to mention a few, software design (Sonnentag, Niessen and Volmer 2006), and mathematics (Butterworth 2006). Sonnentag et al. indicate that expertise in the field of software design is not only researched because of scientific reasons. Global economy is largely dependent on information technology, and the development and maintenance of high-quality software systems are of crucial importance. Accordingly, for practical reasons, it is pivotal to examine how expert performance in software design and programming is achieved. (Sonnentag et al. 2006.) Equally, the situation is similar in the research on expertise in engineering education. Engineering education can well use such research results how to integrate expertise development in the curriculum. Fields with growing significance are shared globally, and, for instance, found in sustainable development, and energy production.

Mäkinen and Olkinuora (1999) conducted a research on academic expertise at Finnish universities. They concluded that regardless of branch, academic expertise should include IT skills, flexibility, social skills, and especially, an ability to choose the most relevant knowledge from information flood. Furthermore, they stated that the ability to renew knowledge and skills continuously according to the ideals of lifelong learning is crucial for knowledge-intensive work. These results can be compared with OECD's DeSeCo findings (Rychen and Salgarnik 2003). Tynjälä et al. (2006) carried out an empirical study among Finnish university graduates in four different fields. They were interested in how university graduates perceived the qualifications and skills needed in their profession and how they saw the role of university education in providing these skills. One of their findings was that technical jobs had become more and more social, and those jobs characterised by social interaction require more and more technical skills. Their finding was that both computer skills and social skills were needed virtually in all jobs where university graduates will place themselves. These findings are somewhat parallel to the OECD DeSeCo study (Rychen and Salgarnik 2003) and US study by Davis et al. (2005).

One pivotal reason for researching expertise and its nature is, on the reverse side of the phenomenon, the threat of professional obsolescence (Pazy 1990). In this context, obsolescence means that learnt knowledge (at university studies) becomes old-fashioned, or, for instance, is replaced by new technology. People in system-analytical jobs are required to update of new

knowledge of their own field. Furthermore, they need motivation and skills for continuing education, and they should acquire a competence in learning to learn through their career (cf. Keltikangas and Allt 2009). Rapid development in particular in technological fields implies that knowledge achieved in engineering education comes obsolete at an accelerated pace (Educating the Engineer of 2020, 2005, 7). Examples of such technological fields could be biotechnology and nanotechnology. Pazy (1990) explored experiences of obsolescence by people at different stages in their professional career. She studied 50 academically trained professionals from high-tech firms in Israel with in-depth interviews. Her results showed that obsolescence was not a uniformly experienced phenomenon, but it meant different issues to different people. Her study stated that human resource executives should pay more attention to career stage differences.

One of the principal encouragers for this research was the dissertation study by Isopahkala-Bouret (2005) completed at University of Helsinki. Isopahkala-Bouret studied narratively information technology experts at an international data communications company. Her purpose was to comprehend how professionals narratively make sense of expertise and how confusing role transitions impact interpretations of expertise. One of her main findings was that those IT professionals (nine respondents) she studied could be divided into two groups; those who had a positive attitude towards learning and "right skills", and those who did not have means or resources to update their professional competence, and whose knowledge was no longer needed. Furthermore, professionals in her dissertation study regarded the change of their own professional role and taking responsibility over new areas as an unavoidable part of expertise.

Another rather significant Finnish study was on learning environments in Finnish higher engineering education (Naukkarinen 2006). The study was a part of the FuturEng-project by the Finnish Association of Graduate Engineers TEK, and it analysed the learning environments in Finnish higher engineering education from the developing information society's viewpoint. It was conducted as a case-study with a narrative approach at three Finnish universities and three units at polytechnic sector. Based on the research data, the result of the study was a conceptual model of the learning environments in Finnish higher engineering education. The model consists of six main constituents: 1) field and industry, 2) (learning) substance, 3) physical environment, 4) cultural environment, 5) administrative environment, and 6) social environment. (Naukkarinen 2006, 123–156.) Two main problems, which both are rather relevant with this topic of study, were the lack of identity of engi-

neering studies, and teacher-centred academic cultures. When I reflect these results to Neumann et al. (2002), there are similarities. The education has primarily been teacher-centred at the Department of Electrical and Communications Engineering. Furthermore, the lack of identity may partly be due to the 'academic freedom' as it has allowed students to decide how to participate into education. In this context, academic freedom refers to the engineering students' incorrect perception of the term – a 'freedom' of not to study eagerly, for instance, not participate in the lectures or exercises. Therefore, many students have not become active members in the community.

This section has compiled an overview of expertise, different definitions for it, and the prior research existing on it, in particular from the engineering education perspective. The most important notion in this study is that engineering education is the breeding ground for students to become experts in one's own domain in the future. Hence, engineers in general are not experts when graduating from the university but they become such in working life. However, this should also be regarded and supported in the curriculum design – seeds of expertise are planted into the students in studies.

2.5 Studying engineering

This section considers studying engineering from several standpoints. When initially learners are relatively alike at universities and institutes of higher education, there are still differences when engineering is compared, for instance, to the educational sciences. In this section, TKK is first viewed as a community of practice according to Wenger (1998). Furthermore, approaches in learning, similar for all the learners in spite of their discipline, are described. The theoretical decisions selected in this study are elaborated in the last section. To go further with the concept of learning, the viewpoint is changed to a different level, to the communities and students as members in them.

2.5.1 Communities of practice in engineering education

In this section, learning is approached as a collective phenomenon. The assumption is that ECE (current Aalto ELEC) is a collective learning context, a community of practice. For instance, expertise or competencies can be adopted from co-members in the community. Simultaneously, Aalto ELEC educates students for working life, where communities of experts representing various fields or disciplines, are very typical.

In the social theory of communities of practice, learning is expected to be an outcome of social participation (Wenger 1998). In general, communities of practice are groups of people informally bound together by shared expertise and passion for a joint enterprise. It, for instance, in this context, can be a group of graduate electrical engineers having studied together. (Wenger and Snyder 2000.) According to Wenger (1998), all people belong to the communities of practice, and they can be found everywhere - at work, at studies, at home, or at free time activities. People may have a different role in each community. Wenger continues that communities of practice are an integral part of people's daily lives. (ibid. 1998) In this work, universities, or their departments, are considered communities of practice. Furthermore, former TKK (current Aalto) as a community of practice can be examined from an individual's, communities', or an organisation's perspective.

According to Wenger (1998, 4–5), a social theory of learning integrates four components to describe a process of learning and knowing. These four components are:

- Meaning: a way of talking about a capability or ability, both collectively and individually, to experience one's life and world as relevant
- Practice: a way of talking about the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action
- Community: a way of talking about the social configurations in which initiatives are defined as worth pursuing and participation is recognisable as competence
- Identity: a way of talking about how learning changes who we are and forms our personal histories of becoming in the context of each community (ibid. 1998.)

Kolikant, McKenna and Yalvac (2006) have another view to Wenger's theory and they depict characteristics of a community as follows: 1) what the community is about, and 2) how the community functions. The writers stress that "there needs to be a mutual engagement by its members" (ibid. 2006). In this study, this is challenging when the university is the community. The members of the community are from different groups (students, teachers, service personnel) and their engagement might also differ from each other. Third, Kolikant et al. (2006) emphasise the capability; what kind of capabilities the members of the community have created.

According to Wenger (1998), practice and identity are the key concepts of the four components. He continues that members of the community need to practice in their shared domain of interest which exists among them. In the theory, he focuses on the identity from a social perspective. In addition, he claims that person's identity includes his/her ability and inability to form meanings that describe communities and people's forms of belonging. (ibid. 1998, 145.) In this study, the concept of identity is considered a combination of Wenger's insight and of narrative approach (cf. Chapter 3.3. about narrative approach). Thus, in this study, the focus is on engineers' identities as narratives of their professional career, and their path in becoming an engineer.

Another aspect of Wenger's thoughts on identity construction is related to the types of communities. He claims that "our identities are constituted not only by what we are but also by what we are not" (1998, 164). Members in the communities of practice select between participation and non-participation, or some degree of combination between them. Depending of the individual, engineering students' participation may quite much vary. Some students consciously choose non-participation which may denote that they complete their Master's degree being a member of the community in the outer circles and they do not necessarily participate in anything but mandatory tasks in the studies. Thus, they do not form a sense of belonging to the community. In opposition to this, there may be students who, besides studies, are very active in guilds and associations in their free time. In general, this is much reflected by the norms and values in the community. Additionally, the tradition of academic freedom has predominated higher engineering education. In practice and at worst, students may have comprehended academic freedom from their perspective as not participating in education, or not taking enough own responsibility of one's own studies. With respect to the community, students may have passed through their studies without any contact to the teaching faculty, or to the peer students. On the whole, students can create several forms of belonging to the community which may affect also their motivation and commitment to study successfully and complete their degree.

The theory on the communities of practice has gradually been adopted in engineering education research as well. For instance, Du (2006) examined learning experiences of engineering students of both genders in problem-based and project-organised learning environment at a Danish university. Her study, which examined gender issues mainly in electrical engineering, was related to the theory of communities of practice. She stresses that "the engineering community is a social entity whereby its members engage in en-

gineering practice and develop engineering competencies". One of her results was that the engineering community shaped men's and women's learning experiences differently. Furthermore, she suggested that the male dominance of the engineering culture has affected the values on knowledge to be perceived as masculine. (ibid. 2006.) A Swedish study (Wiggberg 2010) has examined computer science (CS) student projects as communities of practices. Wiggberg investigated CS project courses at Uppsala University by contrasting students' experiences with teachers' expectations, and based his study on the theory of community of practices. The result of the study was a method based on Wenger's theory. The method is based on identification of the main features in project work, and it evaluates project courses in CS. The target of the method is to create a learning environment through students' experiences. (ibid. 2010.)

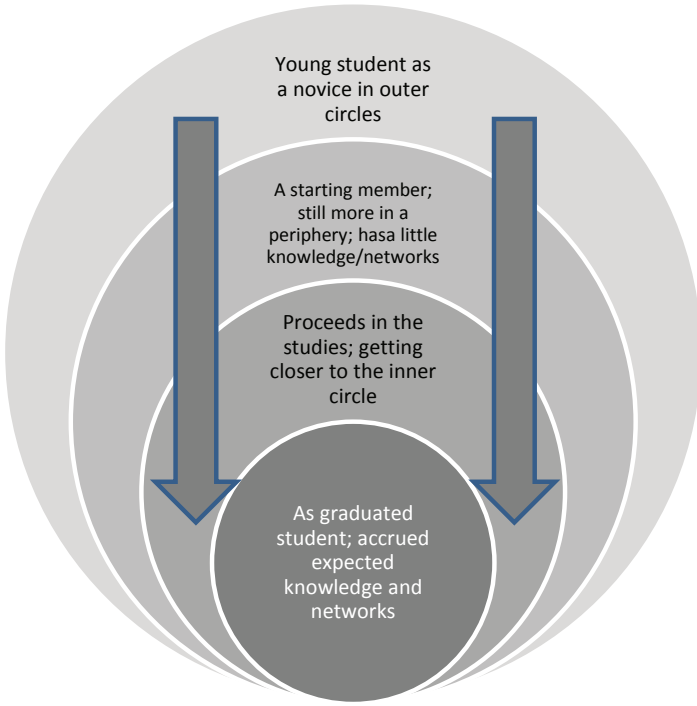


Figure 2. *Student as a member of TKK learning community moving from outer circle towards inner parts of the community (author's original diagram)*

In the data collection there were no direct questions items regarding the communities of practice. However, when I decided that the main emphasis to be on a qualitative data, my expectation was that the idea of communities of practice may somehow come up in the gathered data. The Department of Electrical and Communications Engineering (the current Aalto ELEC) in itself forms a community of learning. When students start their studies in the

first year, they find themselves in outermost circles in the community (see Figure 2). The community should function so that students proceed towards inner circles of the community when they 'maturate' as a member on their path on the way towards the Master's degree in engineering. Regrettably, this community may not have often functioned so. Thus, students after having graduated have remained in the outer circles. In extreme cases, students have not found their place in the community – due to for several reasons they have not been sufficiently motivated to continue their engineering studies and they have changed somewhere else without completing the degree. Concurrently, the development of their identity as a learner and a member has followed the progress of this situation.

In the next section, learning is examined from an individual students' standpoint – through learning styles. The following chapter offers background data for the reader, and as the chapter about disciplines, is meant to support the reader. As in the earlier sections, the focus of the prior research is on the engineering education.

2.5.2 Approaches to individual learning

In respect to how students learn, they do not react to the learning environment as such, but they react to it as they experience it. In other words, students handle the learning environment in accordance with their experience of it. (Bowden and Marton 1998, 8.) Students have different learning styles (Felder and Silverman 1988; Felder and Brent 2005). Felder and Brent (ibid.) define learning styles also as characteristic ways of taking in and processing information. They studied US engineering students for several years and noticed that there are mismatches between common learning styles of students and traditional teaching styles of professors. They suggested that students' learning styles may be defined by asking the following four questions:

- What type of information do students preferentially perceive?
- What type of sensory information is most effectively perceived?
- How do students prefer to process information?
- How do students characteristically progress toward understanding?

They divide learners according to the prior mentioned questions. In the first question, they state that students are either sensory or intuitive learners. Sensory learners perceive external aspects, such as sights, sounds, or physical sensations when intuitive ones perceive internal, for instance, memories, thoughts, or insights. In engineering education, prior mentioned are likely to

be oriented towards facts and hand-on procedures, and are inclined to be concrete and practical. Intuitive learners learn better with abstractions such as theories and mathematical models. In addition, these learners tend to be more innovative with problem-solving which is rather pivotal in engineering education. With the second question, Felder and Brent identify what type of sensory channels students use in learning – do students better perceive visual or either verbal information. Visual learners perceive better, for instance, pictures, diagrams, or demonstrations when verbal ones tend to learn better with written and spoken explanations. Traditionally, electrical engineering education at TKK has used more verbal channels than visual. Teacher-centred mass lectures in electrical engineering have been the most common form of teaching.

As a whole, student learning can be divided into three different approaches; a surface, deep, and strategic (Bowden and Marton 1998). When students learn with surface approach, their intention is to cope with course requirements. Learners focus on surface characteristics of the situation, for instance, the very texts for one exam, or on formulas for solving certain calculations. They attempt to learn the knowledge which is anticipated at a certain task, typically for one exam. Usually, quite soon after the exam they have forgotten the substance they have studied. In the event of failure to recall the substance they have not focused on the meaning of the text. Negative effects for students may be, for instance, that they find it difficult to make sense of new ideas presented and they may feel undue pressure. When the learner has received insufficient foundation in mathematics or physics, learning other domain subjects can be fragmented when using routine-type of memorising the substance.

When learning with a deep approach, the focus is on the object of learning, and the intention is to understand the whole phenomenon. With the deep approach, it is possible to relate ideas to previous knowledge and experience, and students can search for patterns and underlying principles. In practice, their aim is not just to pass a certain examination, but to grasp the entire problem. When learning with the deep approach, students typically become more interested in the course content and also possibly interactively participate in further course development.

The third learning approach is called strategic (Entwistle 1997; Bowden and Marton 1998, 8). Students adopt different approaches in different learning situations; it is not purely one or another. Obviously, the intent in higher education would be that mainly deep approach is used in order to sustain mean-

ingful learning. With the strategic approach students want to achieve the highest possible grades managing their time and effort effectively. They put their consistent effort into studying and attempt to find the right conditions and materials for studying. (Entwistle 1997, 19.)

An investigation at a Finnish university of technology (Ropo 1993) with both quantitative (n=181) and qualitative (30 interviews) study was completed among engineering and architecture students in order to cover approaches to studying and perceptions of teaching. The analysis focused on comparing correlations between the sub-groups of the sample. According to the findings, approaches to studying and perceptions of teaching were related to each other in a complex way when regarded through the pair wise group comparisons. According to Ropo, the results demonstrated that students' experiences of teaching and their perceptions of it were closely related to their approaches to studying and their overall orientation in their studies. (ibid. 1993.)

Biggs (1978 cited in Prosser and Trigwell 1999) has presented a model for understanding learning and teaching in higher education (3P model - Presage, Process, and Product, see Figure 3). With the model, it is possible to discuss various questions about learning and teaching in engineering, such as:

- Is engineering education only transferring knowledge from the teacher to the learner?
- Do teachers in engineering education consider enough that students have various learning styles and they do not all learn in the same way?
- How do teachers consider enough different teaching approaches?
- Are there mismatches between the teaching and learning styles?
- How could teachers encourage students to take more responsibility of their own learning process?

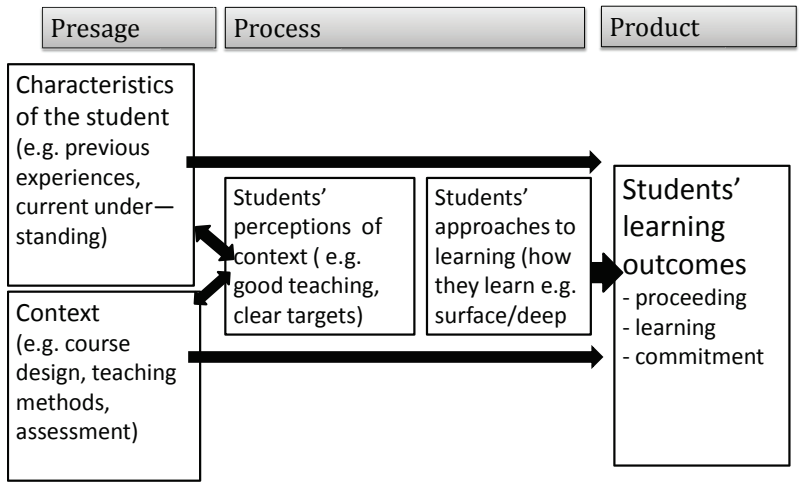


Figure 3. *Presage-process-product model of student learning (Biggs 1978; adapted by Prosser and Trigwell 1999)*

The model presented is an ideal for a well-functioning education system. Students arrive to the university with their previous experiences on learning, and these characteristics interact with the prevailing context at that certain unit. In a well-functioning system students may have positive experiences which facilitate and support their study career. On the other hand, when teachers may have a deeper understanding of the characteristics of the students, they can use that information in course design. With a good interaction of these various factors, teachers may be design and offer good teaching, resulting better learning. University education should aim to teach in a way that students would learn with a deep approach in order to learn for their entire life. When learning with a deep approach, students should comprehend the whole phenomenon and relations in it, and relate the learnt substance to their previous knowledge and experiences. As an outcome, universities 'produce' ideal graduates with holistic knowledge of the major subject.

At Aalto context, it may be simple to point out possible challenges, shortcomings, or problematic areas in each phase following the 3P model by Biggs (ibid.1999). When first-year students enter the university, they form a rather large crowd of heterogeneous young people originating from different backgrounds. Students with a Finnish background mainly have passed the equal educational system. However, Aalto Schools have also a growing number of students from other countries, in particular from the non-EU countries.

These students have mostly completed their Bachelor's degree outside Finland. During the first two study years, the students are traditionally scheduled to pass large basic courses in mathematics and physics. These are rather large mass courses which have been criticised partly because of passive teaching methods and insufficient learning outcomes. Furthermore, it has been noted that minimum score requirements with which students have been accepted to the former TKK, have decreased at least for the mathematics part of the entrance examination. (cf. Rasila et al. 2011.) This has had an influence on the learning in mathematics.

The mass lectures in theoretical subjects have not offered such quality in teaching that students would have learnt the substance sufficiently. Students' experiences on studies during the first two study years may have been either fragmented or not positive enough. Later on, when they continue further to the Master level studies, students may not actively take part in education physically at the university premises, but they participate merely in the mandatory lectures and complete the courses by participating in exams. Most students in engineering education complete their Master's thesis in the industry and have already some years of work experience when graduating from the university. This is somewhat different from other European countries. In Germany and Switzerland, engineering students complete their Master's thesis mainly within the departments and laboratories at the university without receiving a regular salary. There are pros and cons in whether the thesis has been completed for the industry, or for the university. When the students have completed their Master's thesis in the industry, the employers have received more experienced workers.

In brief, when the 3P-model is reflected with respect to the education studied, there exist areas to elaborate. These areas could be, for instance, how the students' current understanding is considered in the Presage phase, or students' learning approaches can be assessed in the Process phase.

In the next section, the theoretical framework presented in this chapter is summarised. The different stakeholders in the study are viewed from an individual student perspective. Similarly, the attempt is made to comprehend potential expectations towards the student.

2.6 The summary of the framework

The aim of this thesis is to describe the context between several stakeholders, or actors: an institution which gives engineering education (Aalto ELEC,

previous ECE), students who have studied there and who graduated from there to the working life, and 'outside world' – the surrounding society. The key issue which combines the parts in this study framework is the design of engineering curriculum and factors which may affect it. It consists of, for instance, the knowledge and the substance what engineering students are studying, quality of education, or the combination of theory and practice in the education. Teaching personnel may see the curriculum from a different point of view; at a level teaching major and minor subjects, or teaching and management at a the degree programme level. The individual students have a more holistic view; how the teaching in general appears to them and how their study path at the university generally goes. Students may have somewhat black-and-white perceptions of the overall quality of the teaching; negative experiences in some courses may trigger prejudices against the teaching in general. This study is about learning at universities, in particular in higher engineering education. The field of various learning theories is so vast that the focus is very carefully on limited approaches related to the subject. When I studied electrical engineers' perceptions of expertise and professional competencies, it was significant to think of the whole context *why* engineers are required to gain expertise and competencies and secondly, *how* and *where* they will gain them.

The learning process cannot be regarded merely from the students' individual and personal development perspective. It is also significant to discuss the benefits of the education for the surrounding society. At the national level in Finland, Ministry of Education and Culture (http://minedu.fi/OPM/Koulutus/ koulutuspolitiikka, 2010) has defined the following objective for Finnish education policy: "*The priorities in educational development are to raise the level of education among the population and the labour force, to improve the efficiency of the education system---*" In this context, it may be noted that the definition includes a notion of 'labour force' and does not point out students or individuals. The Ministry has also stated (ibid. 2010) that universities have to "provide higher education based on research, and educate students to serve their country and humanity". In Aalto education, these perspectives are not often mentioned. It could be claimed that the current generations of young people studying at universities are growing into experts in a very global society wherein, for instance, networks and connections used are dissipating earlier images of nations and advantages brought to them by the university education.

The engineering curriculum is connected with the society as well. It signifies, for instance, that the official level, the Ministry of Education and Culture

in Finland, defines the targets of higher engineering education, and has expectations for the education in the form of numbers of graduate and doctoral degrees completed annually. The curriculum also reflects on the needs and changing trends of the industry and working life. In particular, higher engineering education has a challenge to meet the needs of the industry. Higher engineering education is taught at science universities, and therefore the middle course between theoretical and practical substance needs to be taken. There have been debates about the practical needs from industry meeting scientific targets in higher education. Aalto School of Electrical Engineering as a scientific university has to maintain a high level of scientific theoretical substance in the teaching. Thus, it cannot follow all the potential altering economic trends in the industry, in particular when companies globally live in a world of 'quartile economy'. Furthermore, a factual challenge for the universities in engineering education is to be able to forecast potential future needs for scientific research and educational development. Another challenge is the universities' various resources to advance these areas together in balance with other stakeholders.

During the past decades, engineering education has met the challenges of more and more rapid development of globalisation and information society which without doubt has its reflections to the education. Thus, the education does not exist in a vacuum but is affected by the aforementioned factors (different stakeholders). Engineering education in Finland, in particular in electrical engineering, has not been explored much yet. With the model in Figure 4, I attempt to grasp this field also from the cultural viewpoint of the engineering education, both formal and informal culture. An individual, the student who will begin his/her studies at this university, brings along earlier experiences including his/her cultural background received at home, school, or in other areas of life. All these likely factors are included in the meaning-making process toward the degree and development in engineering identity and thinking. I claim that the cultural aspects and students' earlier learning experiences are not taken sufficiently into account when designing engineering education.

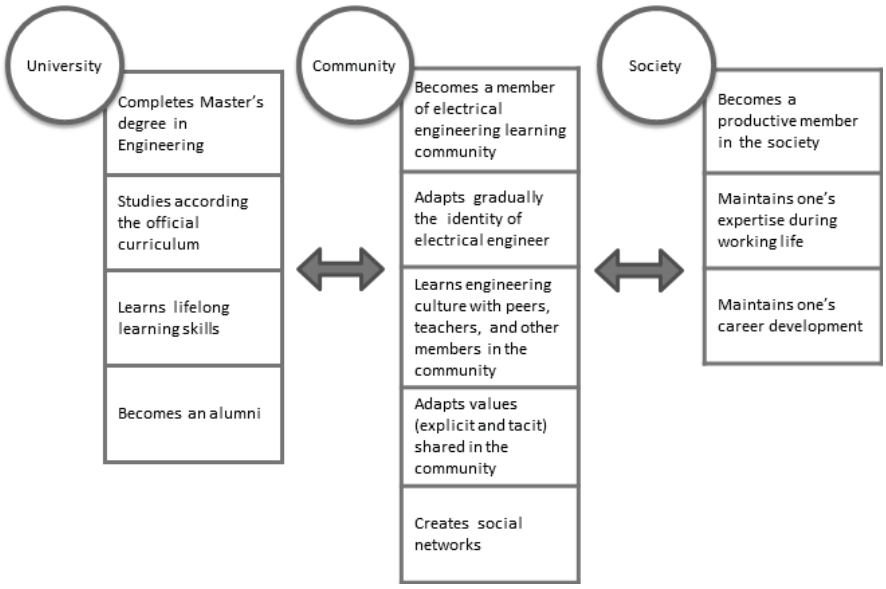


Figure 4. *Expectations for an individual engineering student from different stakeholders' point of view (author's original diagram)*

In the Figure 4, expectations to an individual student are viewed from different stakeholders' point of view. The expectations collected in all three pillars in the figure inter-relate and overlap with each other. Furthermore, rather many of them are tacit, for instance, not explicitly documented in the curriculum for the students.

The study tries to approach this field from individual student's point of view based on data collected with a mixed methods approach. The central point in this work is to aim to view this field from an individual student's perception; how an individual studying process is connected to the community, and to the curriculum. The individual student perceives and experiences his/her studies and study time at university always from one's subjective, personal premise and only gradually begins to identify him or herself as a member of a larger community. Concurrently, the professional identity should be developed, and the foundations for the growth in expertise received during the engineering education. Considering the student as a talented, unique individual from the beginning of the studies can guarantee better learning opportunities and processes when completing an academic degree and accruing skills in learning to learn.

3 Research methodologies and data collection

3.1 Background for the research methodologies and data collection

The data for this study were collected with both quantitative and qualitative methods (mixed methods). However, the main research approach has been qualitative. According to Creswell (1998, 17), I wanted to find answers for questions "how" and "why". After having studied prior research of this field, this topic needed to be more thoroughly explored than merely with quantitative methods. There existed a large amount of prior research on expertise and professional competencies, but not in particular on the electrical engineering field. My research environment in higher engineering education was extremely wide: from professors to all members of teaching personnel, current students, graduate students, representatives of the surrounding society, for instance, industry and other employers, or the Finnish state.

From the beginning, the focus of the research has been on graduate electrical engineers. Two types of data collection were completed in this study, quantitative and qualitative. The main focus in the quantitative data collection has been on adults who have graduated from the former Department of Electrical and Communications Engineering, or whose studies in electrical engineering had been delayed. By electrical engineers, I refer to these aforementioned groups as a single group of adults who have the equal type of educational context; or a community in which they have studied.

The assumption in this work is that the identity of the student will be shaped professionally, culturally, and socially regardless of the engineering substance or different physical, social, or cultural environment at the technical university. The decision to use mixed methods was due to my expectation to gain a deeper insight into the process of becoming an engineer. When using mixed methods in data collection and analysis, it is necessary to clarify which terms have been used in relation to the research paradigms and epistemology. Koro-Ljungberg et al. (2009) refer to epistemological awareness. The term is connected, for instance, with the openness and transparency of design choices, purposes of the research, and trustworthiness. The research process in particular with doctoral theses must be well documented and transparent, including the choice of methodology and data collection. This is also in conjunction with the terminology. Typically, each research methodology uses its own terminology in order to document each process. In this process I have used mixed methods both in data collection and analysis; it has

brought me many challenges which I have attempted to solve as well as I could.

3.2 Research questions

In this work, I have studied experiences of a certain group of electrical engineers with quantitative and qualitative methodologies. I interpreted the interviews of graduate electrical engineers and reconstructed these into narrative stories. The starting point was to attempt to describe the world how the respondents have experienced it. Decidedly, I did not choose a gender or a profession research approach, but I examined the topic from the engineering studies' viewpoint. The stories are not generalizable but still they can indicate phenomena in this research area. In the subsequent sections I describe the data collection and the analysis methodology. With constructivism in the foundation of this study, I have used terms 'experience', and, for instance, its synonyms 'views' or 'viewpoints' in the instantiation of the narrative stories. Furthermore, I have attempted to formulate my research questions according to the constructivist perspective: **How** do engineers and engineering students with delayed studies in my sample groups **describe** those different areas I ask them about in both surveys and interviews. The perspective has also a connection to my own views on engineering education and on its development. In this work, the attempt is to search areas to elaborate in engineering education.

The research questions in this study were:

RQ1	How do electrical engineers describe their studies at TKK?
RQ2	How do electrical engineers perceive expertise and professional competencies?
RQ3	How do electrical engineers describe their engineering career?

The answers to the aforementioned questions are documented in Chapter 5.

3.3 Mixed methods or bricolage – combining two perspectives

This research has combined two different types of research methods which in methodological literature is called mixed methods approach (cf. Creswell 2009). The intent of using two internet surveys was to receive overall knowledge of the theme and to cover the research area; engineering education and the 'targets' – graduate engineers and the students with delayed studies at ECE. With quantitative surveys I attempted to find out possible

phenomena in the field and use the findings in order to design the interviewing structure for the qualitative phase. In this research I used sequential mixed methods which start with a quantitative phase and continued till the qualitative phase. Creswell (2009, 4) states that "the overall strength of a study is greater than either qualitative or quantitative research". The collected quantitative and qualitative data can underpin each other, and possibly gain a better insight into the topic. The results have also a practical advantage; they can give further information to the developers of electrical engineering studies at the university.

Creswell (2009) mentions that "mixed methods research approach is an approach to inquiry that combines or associates both qualitative and quantitative forms. It involves philosophical assumptions, the use of qualitative and quantitative approaches, and the mixing of both approaches in a study." Furthermore, statistical and text analysis can both be used in a mixed methods study. My purpose has been to use quantitative data to assist the interpretation of qualitative data. According to Creswell (ibid. 2009), the main weakness of sequential mixed method is the length of the time involved in data collection, with the two separate phases. In this study, the time length has been approximately from November 2006 (the time of the first internet survey) till September 2008 (the last interviews conducted), which is a rather long time. I have well noticed this as a researcher. At the time of completing the dissertation thesis it is rather hard to recall details of the earliest phases of the research in autumn 2006. Another weakness that impacts the length of the study is that I have worked with the research topic alone. When working in a research group, the sharing and discussing one's research topic may affect in a positive way the time management, in particular in the phases of data collection.

This research and its data are unfolding electrical engineers' perceptions on studies in electrical engineering, expertise, and competencies. Perceptions were collected with semi-structured interviews. Consequently in the interviews, interviewees were describing their career and lives from the time before entering engineering education up to the present time in their current jobs and work tasks. The methodological philosophy of this research is based on the concept of *bricolage* (Denzin and Lincoln 2000; Kincheloe 2001; Berry 2006), and in particular narrative bricolage. The *bricoleur* who interprets the collected data understands that research is an interactive process shaped by his/her personal history or biography. S/he also understands that it is shaped by those of the people in the setting – in this research electrical engineers and the learning community. When completing a research in an inter-

disciplinary area, the term bricolage can well be justified. *Bricoleurs* are picking up the various pieces and pasting them together. Denzin and Lincoln depict that being a bricoleur is "learning how to borrow from many different disciplines" (2000, 3–4). According to Kincheloe (2001, 681), bricoleurs "recognise the limitations of a single method, and combine several methods". When I completed my dissertation study in a rather new, cross-scientific field, it was likely to adopt the basic ideas of bricolage.

3.4 Narrative approach as a methodological decision

The narrative approach for analysing the interviews was selected in order to describe respondents' perceptions and experiences in a story form following their life phases. Widely interpreted, it could have also been possible to use life history research or inquiry (Cole and Knowles 2001, 11). With the aforementioned approach, it is possible to understand human situations and conditions, and furthermore, to understand interaction between life and context, or self and place. But in this study, the narrative approach was chosen due to the delimited areas of life; studies and work in engineering field. The data collected in a narrative approach can either be vocal, written, or visual. The choice in this study was to collect vocal data in a form of interviews.

Polkinghorne (1995) states that "narrative refers to a discourse form in which events and happenings are configured into a temporal unity by means of a plot". Furthermore, Riessman (2008, 11) describes that "narrative analysis refers to a family of methods for interpreting texts that have in common a storied form". She continues that although it is case-centred, it can generate "categories" or general concepts, as in other case-based methods (ibid. 2008, 13).

The word 'narrative' comes from Latin – '*narratio*' (noun) means a narration or a story. Furthermore, *'narrare'* (verb) means to tell. Narrative approach has its roots already in ancient Greece. In the methodological literature it is often mentioned that narratives origin from Aristotle's tragedies which consist of a beginning, middle, and end (Aristotle 1968 cited in Hyvärinen 2007, 448). Adapted to this study, these stories consist of four phases; time before beginning (time before studies), beginning (studies at TKK), middle (working life after graduation), and the future. The difference in this study is that I do not see the future as an end but as an on-going cycle of learning.

The narrative approach can be perceived as if the story was the meaning of the whole research process and the function of the researcher (Connelly and Clandinin 1990). In narrative research, the interests are in the stories, the processes, and changes and transitions in them (ibid. 1990, 21). These stories focus in particular on learning and higher education in engineering. Webster and Mertova (2007, 1) claim that narrative approach is "well suited to addressing the complexities and subtleties of human experience in teaching and learning". Andrews, Squire, and Tamboukou (2008, 5) offer one theoretical division in contemporary narrative research – event- and experience-centred narrative research. First, event-centred focuses in particular in past events that have happened to the narrator, the person in the research telling the story. (ibid. 2008) In the latter, the narratives can be sequential in time and meaningful, and "re-present", or re-constitute experiences. Likewise, experience-centred narratives can display transformation or change. (Squire 2008, 42.) Because of the sequential questions in these research interviews, I assumed to be able to collect experience-centred engineering career stories when having designed interview questions in four time phases.

Another way of classifying and organising narrative research is by Lieblich, Tuval-Mashiach and Zilber (1998, 12–14) in which they present two dimensions: 1) holistic versus categorical and 2) content versus form (see Figure 5). The holistic dimension refers to a type of analysis in which the text or the narrative is analysed as a whole. The other end of this dimension, categorical perspective, is rather similar to content analysis approach. In this approach, the narrative is dissected, for instance, into sections which are analysed and turned into categories which then are collected from many stories. The key difference could be stated to be the number of people in question. In the categorical approach, the researcher is mainly interested in a phenomenon or a problem common to a group of people whereas the holistic approach tries to focus on one individual and his/her experiences as a whole. (ibid. 1998.)

In the second dimension, content versus form in a story, researcher can focus more on the content of the story, or what type of form the story has. When searching for the content, a researcher may concentrate on questions what happened in the story or why, from the teller's viewpoint. Those who focus on the form attempt to study, for instance, the structure of the plot, or the complexity and coherence of the story. (ibid 1998, 12–13.)

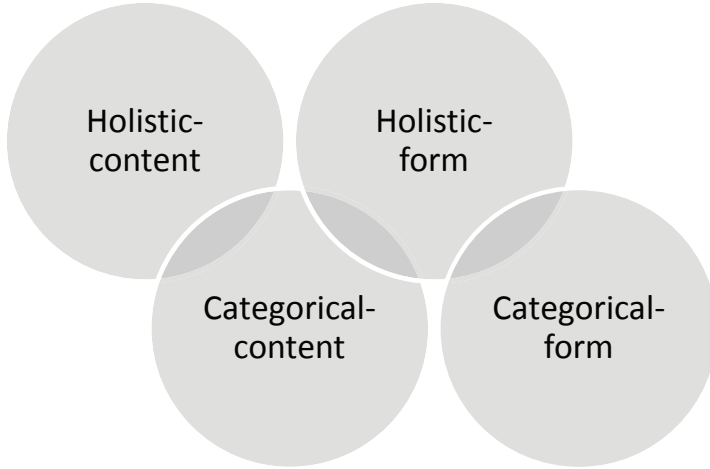


Figure 5. *Visualisation of the dimensions of narrative analysis (author's original diagram according Lieblich, Tuval-Masciach and Zilber 1998)*

The research in this study is data based and principally following the categorical–content form. I have studied the narratives and found connective categories between the respondents. However, phenomena and categories found in the narrative stories are not treated as quantitative data but described contextually. The focus has been on the content of the narratives, not on their form, or their coherence.

An idea of reconstructing the told from the telling was applied (Mischler 1995) in this research. Mischler explains this that usually respondents or interviewees do not tell about their lives in temporal order but, for instance, in an interview jump from another stage in to an earlier one and do not follow chronologically the life stages. In this case, the researcher can reassemble selected episodes from their interviews and other data sources into a chronologically ordered series. (ibid. 1995.) Compared to a life-story narrative, the collected interviews in this study depicted a more restricted story. One approach to the life narratives studies are turning points in somebody's story. This approach was not purposely chosen, but my presumption was that some respondents may tell about turning points in their work-histories as the collected data were data-driven. The subjects told about the time before their higher education, their engineering studies, their work now and earlier, and their future prospects in working life. The diverse stages of their engineering career were in my focus, and through their interviews I studied their stages of career through which they achieved their current work identities, or roles. The research takes both backward-oriented as well as forward-oriented perspective, but at the same time it focuses on the present of 'telling moment'

(Bamberg 2006). The questions I asked from the respondents were rather wide; the person could select his/her own time perspective. The narrative approach also means another two-fold perspective: the collected engineering narratives are simultaneously a starting point and a result of the study. Methodologically, this study might be among the first ones in engineering education using narratives as a method of data collection and a way of thinking and constructing a dissertation study. As a result of the study, engineering narratives reflect one part of educational reality at a technical university.

One of the particular themes with narrative approach is coherence. The narrative stories formed in this research aim to describe coherent engineering stories of electrical engineers. According to Hyvärinen, Hydén, Saarenheimo and Tamboukou (2010), narratives can be conceptualised in terms of coherence: temporal, linguistic, and sequential, to mention some. Coherence in particular regarding to this study means that the narratives of electrical engineers are temporal. Moreover, I formed the narratives in a linear, chronological way, from the beginning through middle stage till the end which in this study was the future. Squire (2008, 53) claims that coherence from the researcher's point of view could not be what ought to be mentioned in the stories, or how events "should be talked about". Stories may have narrative coherence in spite of the researcher's expectations. Through narratives which interpret stories of persons' lives, it is possible to find out how our 'self' or our identity has been formed. (Hyvärinen et al. 2010.) The stories described in this study focus on the sub-part of people's lives: the stories of the respondents becoming electrical engineers.

Moreover, another thematic issue in narratives is a plot (Polkinghorne 1995, 5). Usually, it may be stated to be connected with literature, plays, and drama. In narrative analysis, the plot is the thematic thread, and the integrating operation is called an emplotment. In narratives, when happenings in somebody's life are configured or emplotted, Polkinghorne claims that "they take on narrative meaning". The emplotment in my study is following the various plots in the lives of the respondents. With the four time phases of interviewing questions, I have attempted to follow the plot of their lives and turn their stories into a narrative meaning. With respect to plots, I have also attempted to search turning points or transition phases during their career which may have had significance in their lives from the professional career point of view.

3.5 Validity, reliability, and verisimilitude of the study

The quantitative research design and methodology were checked against the main criteria of internal and external validity, reliability, and objectivity (Denzin and Lincoln 2000). Furthermore, the study was evaluated according to comparable criteria used in qualitative research; credibility, transferability, dependability, and reflexivity, which together form trustworthiness; the extent to which one study meets these criteria (Lincoln and Guba 1985). Due to the narrative approach, it was also needed to assess verisimilitude or truthfulness of the narrative stories. These concepts are broader than the validity, and used more often in the narrative context (Wells 2011, 113).

Validity in this study in general means how the received results correspond to the reality of electrical engineering education. The practical situation of the study was to examine students' perceptions at one particular department and the correspondence of the results to that reality. The internal validity measures how well surveys served as questionnaires. The first and the second questionnaire differed somewhat from each other, and thus, the data and results of the two first phases cannot be fully compared. The length of the research project affected the design of the phases. In the beginning of the project, I did not have as much background knowledge of the area as I had one year later. In case I could re-design a survey questionnaire now, I would use all the knowledge gained through this whole study, and the question items would be somewhat different. It would consist of more questions on the substance of electrical engineering education; for example on quality of teaching, quality of used teaching methods, and in particular how students regard the faculty as a learning community.

External validity represents the fact how well the study can be generalised, or whether the same results can be derived on repeated trials. Validity also means how the study and its instruments measure what was intended to be measured. The basic research context has been the former Department of Electronics and Communications Engineering. However, the basic engineering education given in general at the current Aalto ELEC has not entirely differed from the time at TKK. Thus, it can be claimed that the results can be generalised in some degree in other units at Aalto. The qualitative part of the study, narrative interviews, represents the reality of the participants in this very study and thus cannot be directly generalised into other engineering areas. However, they possibly reflect the same phenomena discovered in the other engineering education studies. This enables potential connections between these results to other engineering fields.

Using two different types of research collection methods, surveys and interviews, ensured that the data gathered were of different kind, quantitative and qualitative. When two or more different research methods are used at the same time, it can be called concurrent triangulation (Cohen and Manion 1994, 233; Creswell 2009) which strengthens trustworthiness. However, in this study, the data were collected with different methods in two different time phases. Thus, I used sequential transformative strategy (Creswell 2009, 213). In the initial phase, I collected survey data which provided exploring the research field, and finding possible themes and phenomena. The second qualitative phase was constructed on the previous one. In the first phase I gained a theoretical lens into the field of the study which facilitated understanding the phenomena, and designing the questions in the interview phase.

The internet surveys were sent to a large group of respondents who voluntarily decided to complete them. The interview respondents were chosen by random and purposive sampling. They were selected across a range of 1) status (scientific-oriented vs. industry-oriented career), 2) gender, and 3) major subject area at ECE. My researcher role as an interviewer was partly biased. The work experience at ECE, eventual previous acquaintance with some of the respondents, and the subjective character of the interviewing sessions, affected somewhat the interviews and could cause some bias.

Based on my previous experience in collecting research interviews, quite often in the beginning of the session interviewees tend to answer 'expected aspects'. They believe that the researcher has something specific in his/her mind, and they tend to reply according their own expectations. In the beginning of each interviewing session, I emphasised that there were no 'right' answers or perceptions I expected from them, but the research was all about their own life, and career. I also explained that their interviews were to be transferred into narratives after having collected them all. These narratives, by Webster and Mertova (2007, 89), are "not meant to be read as an exact record of what happened, nor to be a mirror of the world 'out there'".

One validity strategy in qualitative approach (Creswell 2009, 191) is to use rich, thick description to convey the findings. In section 4.2 with the open-ended answers in the second survey, I selected at least two or three answers in each category to describe one finding respectively. As to the interviews, I transferred them into narrative stories according to the same time periods as I used with the questions in the interviews. Furthermore, when forming the narratives, I read the basic data numerous times in order to find descriptions

thick enough. The part of the stories in the thesis is relatively long in comparison with the part of survey findings. Decidedly, my aim in this work has been to emphasise the qualitative findings. With respect to the narrative stories, when having used rich, thick description, the results may be applicable to other settings which provide transferability.

When using narrative approach, it is necessary to consider verisimilitude (or truthfulness) of the stories. This means in my research that how I have reported the stories and their events should resonate with my experiences as a teacher at ECE. Next, the stories I have reconstructed from the original data should appear credible. (Webster and Mertova 2007, 99.) To verify the credibility of the stories, I sent them on to the interviewees. Each of them read his/her story. Very few comments or corrections were sent back to me. According to Riessman (2008, 189), there is a relation between coherence and truthfulness. In this study it denotes, for instance, whether the time phases in each career story give the full picture, or form a credible and coherent story. Another thing to assess could be whether there are gaps or inconsistencies in the stories. Again, this was checked with the respondents of the interviews – they provided rather few corrections or comments on their own stories as I had reconstructed them, and mainly noted that they agreed with them.

In general, the data collection and methodological choices in this study have been challenging due to the cross-disciplinary nature of the topic. Another challenge with respect to this study is the potential audience reading the thesis. I assume that the expected target audience consists mainly of engineers whose education is based on scientific and more codified views. However, in order to enhance research in engineering education, it is pivotal to use more alternate methods to cover the needs of the growing field. Therefore, as the study was completed with the mixed methods approach; it offered a good opportunity to acquire experience on new research approaches and methods.

3.6 First internet survey

3.6.1 Data collection

In this section, the sample group in the first survey and the proceedings of the data collection are described. In the beginning of the research project I decided to use quantitative data collection in order to receive basic information on the research area. The purpose of the collected quantitative data was to help building up the conceptual understanding of the phenomena in this field. I had no prior experience in this particular research area. Thus, I desired to find out about the possible phenomena.

In November 2006, in the first quantitative phase of the study, a short internet survey was sent by e-mail (see Appendix 2, Appendix 3) to engineers graduated from ECE. The contact information of the respondents was received with the help of TKK Alumni network. At the time of the first study, the network had a total of 9 230 registered members, of whom approximately 1 500 had graduated from ECE. The survey was sent to 602 people who had registered themselves in the alumni network, had begun their studies between the years 1985 and 2000, and had given their permission to receive e-mails connected to study surveys at the university. Therefore, the population represents a professionally active community of electrical engineers who prefer to maintain connections to their home university during their professional career. The e-mails were sent by the co-ordinators of the alumni network due to the Finnish data security laws. An invitation letter was designed to the survey (see Appendix 1) which the alumni co-ordinators integrated into their e-mail. Due to non-valid addresses 20 e-mails were returned. The invitation to the survey was sent twice in November 2006.

In the first survey, 32 questions (see Appendix 2, Appendix 3) were designed on the education of electrical engineering and particularly on electromagnetics education. Likert-type scales were used for answering the questions. In the first survey the scales were used in a reverse order from which they are typically used. Option *very well* corresponded to Likert-value 1 while *very poor* was 5. Afterwards, I could consider this as a mistaken decision. When I compared the data and the results of both surveys, this was somewhat bothering the study. The questions were for example about the studies in electrical engineering and what perceptions of the overall quality of the studies there were. The questions regarding background information were partly

based on an earlier survey research designed by Pylkkönen (2006) at TKK Lifelong Learning Institute Dipoli. She studied the needs of adult learners at the Helsinki University of Technology, and electrical engineering students formed a minor part in the study (164 students out of the entire sample of 571). According to the statistical systems of Ministry of Education and Culture the definition 'adult learner' stands for such students in higher education who are 25 years and older.

The questions were divided into three different sections: 1) background information, 2) questions about the courses and learning at ECE, and 3) questions related to the substance of the studies and work experience. The survey was pre-tested with three engineers recently graduated from TKK, and one senior professor with a long experience in research and teaching. Re-focusing and correctives to the survey questions were completed according to their remarks.

3.6.2 Description of the first respondent group

Altogether 99 electrical engineers completed the first questionnaire. The response rate (17.0%) is not high but may be considered satisfactory for a random, heterogeneous group. A research (Sheehan 2001) showed that response rates to e-mail surveys have significantly decreased since 1986. In the study, Sheehan claimed that the increased amount of surveys and the enormous increase in unsolicited e-mail to Internet users might be reasons for the decrease. (ibid. 2001.)

The respondent group consisted of 23 females and 76 males (see Table 3). The largest group of the respondents were born in the 1970's and were between 26 and 35 years of age at the time of the study. Most of the respondents (78%) lived in the Finnish capital region. A majority of respondents were recently graduated: half of the respondents had from one to five years of work experience. Approximately one quarter of the respondent group answered that they were pursuing doctoral studies at the Helsinki University of Technology or at some other technical university. This can be regarded as a bias within the reliability of the collected data; at least a feeling of solidarity towards other researchers may motivate on answering others surveys. Doctoral studies in engineering can have a positive influence on the answers about the quality of studies. Furthermore, it may be possible that the respondents with doctoral studies are more active to answer to this type of surveys.

Gender (n=99)		Decade of birth (n=99)	
Female	23	1940's	1
Male	76	1950's	2
		1960's	27
		1970's	56
		1980's	13

Residence	(n=99)
Finnish capital region (Helsinki, Espoo, Vantaa, Kauniainen)	77
Other city in the province of Uusimaa	5
Other provinces in Finland	17

Work experience in years	(n=99)
1-5 years	49
6-9 years	31
10-14 years	11
15-20 years	5
over 20 years	3

Pursuing post-graduate studies at TKK or other technical university (n=99)	
Yes	23
as a full-time student with funding	13
as a part-time student (within main work)	10
No	76

Table 3. Frequencies of the background variables of the first respondent group

3.7 Second internet survey

3.7.1 Data collection

The data for the second research phase were gathered during October–November 2007 also with an Internet survey. The survey was sent to 626 electrical engineering students, whose addresses were received from TKK Student registration office. As in the first survey, due to Finnish data security laws, Student registration office formed one collective e-mail address of all the students' addresses. Thus, I could send the link to the survey and the invitation (see Appendix 4) to participate without knowing the personal addresses of the potential participants.

The students in this sample group were delayed in their studies. In this context, they had studied seven years or more at TKK. Furthermore, they had

completed more than 80 study weeks (the unit of the old system, corresponds to 5/3 ECTS points) and were registered in autumn 2007 at the Department of Electrical and Communications Engineering. This sample group was particularly selected because of their current study situation. They were still expected to complete their Master's degree by the end of July 2010, when the former degree requirements changed. The Study Administration at Aalto ELEC had not sufficient data on the study delay reasons, and the results of this survey could gain insight into the possible reasons for delay.

The second Internet survey (see Appendices 5 and 6) consisted of 36 question items in all, of which two were optional, open-ended metaphor-type qualitative questions. The majority of the questions were taken from the first survey with some minor amendments. The survey had two multiple questions on professional competencies in working life. The questions on competencies were adapted from the Finnish academic research project by Mäkinen and Olkinuora (1999). With the specific two questions the aim was to cover more of the research field before entering the qualitative part of the research.

The model for the metaphor questions was adapted from the surveys of the Finnish Association of Graduate Engineers TEK. In these questions, the respondents were asked to continue a phrase with as many words or sentences as possible. The open-ended questions to answer were as follows:

- Engineering expertise is… Would you please continue this phrase with as many words as possible
- Scientific thinking is… Would you please continue this phrase with as many words as possible

These two open-ended questions were located in the end part of the second survey.

3.7.2 Description of the second respondent group

Altogether 120 respondents completed the second Internet survey. The respondent rate of the entire survey was 19.2% which was somewhat higher than in the first survey. 109 respondents of the entire group answered the open-ended qualitative questions. This can be regarded as a fairly satisfactory return in comparison with the entire sample of respondents, especially when considering that answering the two last questions was optional. The response rate to the qualitative questions was 91%.

The average age of the second respondent group was 32.6 years. Thirteen of them were women (10.8 %), and the rest 96 men (89.2 %, see Table 4). This

represents rather well the share of women studying at the Faculty of Electronics, Communications and Automation. The share of women studying at the entire TKK has during recent years been approximately 25%.

Description of the respondent group in the second survey	Freq.	%
Gender		
Female	13	11
Male	107	89
Total	120	100
Work experience in years		
1-5 years	79	66
6-9 years	19	16
10-14 years	11	9
15 and over years	11	9

Table 4. *Description of the respondent group in the second survey*

The largest proportion of the respondents in the second survey had work experience from one to five years (see Table 4). One third of the respondents (70.5% out of 120) was working in research and development tasks (32.5%) and approximately one fifth (19.2% out of 120) in systems and software engineering tasks. The share of the other branches was rather small; each under five per cent. The expectation was that this group of students would not be active, full-time students any more, but in working life. Only 10 respondents of the total 120 were full-time students, which supported this expectation. The major reasons for their delayed studies and graduation had been a full-time or a part-time job, their financial situation, and motivational reasons with studies. Students typically in the later phase of their studies may have to work to maintain their financial balance with the cost of not using sufficiently time for their studies as in the beginning. Thus, not being a full-time student and losing the connection to the studies may cause various delays and possibly increase lack of motivation.

The survey consisted of one question on respondents' graduation plans from TKK as well. The majority of the respondents (97 % of 120) replied that they were planning to complete Master's degree in a two or three years' time before the forthcoming change of the degree regulations in year 2010. Later on, in year 2010, ELEC had a record number of graduates (486), which was

the case at other technical faculties at TKK as well. Due to the anonymous responding system of the survey, I am not able to verify how many of the respondents with delayed studies actually did complete their Master's degree in Engineering at this School.

3.7.3 Method of analysis in the second phase

The primary quantitative questions were analysed with SPSS (Statistical Package for the Social Sciences) statistical programme as in the first survey. The collected qualitative data - the answers of the respondents' – were collected into a one document. The collected data of the two open-end questions consisted of 22 pages of text transformed into Windows Word Table-form from the original Internet survey file. I analysed textual data using a content analysis method. Krippendorff (2006) defines the method as "a research technique for making replicable and valid inferences from texts to the contexts of their use". Content analysis is one of several qualitative research approaches used in educational and social sciences, and increasingly more in engineering education research. In this research, the content analysis was derived from the collected contextual data. It can be regarded as a wide theoretical framework which is possible to be incorporated within several, different analysis contexts.

I read the contextual data repeatedly. Most respondents had written at least three or four longer sentences. Furthermore, quite a few had written an extensive response. After having read the body of text several times, it was possible to find categories describing respondents' perceptions. Three different categories were found based on the collected data. Respondents' answers were numbered per each person in the data. Numbers used with quotations in the Chapter 4.2 (Results of the survey) refer to persons and their perception describing each category. The numbers are combined with a letter "R" referring to the English word respondent. Due to confidentiality reasons the original texts of all respondents are not included in the study. Instead, such excerpts were selected to the results which according to my opinion describe well and broadly the categories.

3.8 Interviews

3.8.1 The sample group in interviews

I gathered the data for the last phase of the study from May to October in 2008 with qualitative in-depth interviews. I selected twelve subjects to the research using purposeful and random sampling (Lincoln and Guba 1985; Wells 2011, 19). According to the narrative approach tradition, interviews of twelve subjects were methodologically sufficient to receive trustworthy data. Regarding the number of interviews, with twelve I could reach the saturation point in a sense of career; the stories began to succeed each other by a rather equal path. Some of the subjects had volunteered for a research interview in the surveys. In the first survey, their optional participation was asked for the third phase of the study. In the final, separate question in the survey, I had asked their contact information for the interview. As to the remainder of the subjects, I asked them to join the research based on their main subject at ECE, their work experience, and attainability to the interview. I first contacted them by a phone call, and after the phone contact I sent an e-mail describing the details of the research (see Appendix 7). The entire group of subjects lived in the Finnish capital region. Furthermore, all of them had a permanent full-time job.

All the subjects were electrical engineers graduated from ECE (current Aalto ELEC). Furthermore, they had more than 10 years of work experience, excluding one with five years' work experience. Eight of the interviewees were male (67%), and four female (33%). The female subjects in this study represent a comparatively larger share than the average percentage (13%) of women studying at ECE (see Table 5). However, the share of women in the interview study was rather similar to the one at the entire TKK.

Background information of the interviewees (n=12)	
Female	4
Male	8
Current job in industry	8
Current job in research/science	4

Table 5. *Background information of the subjects*

The subjects were primarily selected according to their field; they were either research- and science-oriented, or industry-oriented engineers. A few were selected because of their work experience as an entrepreneur. Second, they were selected according to the laboratory from which they had graduated from the previous department. ECE consisted of 20 laboratories, and the interviewees were selected from this range representing six laboratories in the research (see Table 6). Later, after the organisational change in 2008, all the laboratories of ECE were merged into seven departments, and the Department became the Faculty of Electronics, Communications and Automation. From the beginning of 2011, the Faculty was transformed into Aalto University School of Electrical Engineering (*Aalto-yliopiston sähkötekniikan korkeakoulu* in Finnish) with the equal aforementioned departments.

The respondents had graduated from TKK during the years 1986–2003 (see Table 6). Based on the years the respondents may be divided to those who graduated during the economic boom in the end of the 1980's and those during the recession period during the first half of the 1990's.

Interview respondents (n=12)			
Major subject (Master's thesis completed) at ECE		Graduation year from TKK	
Electric circuit design	1	1986	1
Electromechanics	4	1987	1
Power electronics	2	1988	1
Power systems and high voltage engineering	1	1991	3
Radio science and engineering	2	1992	2
Telecommunications	2	1994	1
		1996	2
		2003	1

Table 6. *Major subjects and graduation years of the subjects*

3.8.2 Interviews as a form of data collection

In this research, interviews were selected as the main data collection method. Interviews are one of the most common ways in collecting qualitative data (Fontana and Frey 2000; Kvale 1996). I selected in particular semi-structured, thematical interviews because of the character of the research. The question items of the interviews were designed based on the theoretical framework, the methodological approach, and the data gathered from the two

surveys (see Figure 6). The respondents answered to the same set of questions in the same order. The questions were posed in Finnish, and translated afterwards into English for this research thesis (see Appendix 8). The participants were asked to outline their perceptions on their reasons for entering the engineering field, their study experiences at ECE, their competencies and their work experiences after graduation, and finally how they saw their career in the future. Furthermore, they delineated their own perceptions on expertise and scientific thinking. The data collected on scientific thinking were excluded from this study because of focusing the research area.

The position and the attitudes of the researcher influence interviews; I as the researcher have an active role in the interviewing situations. Furthermore, my background as having worked at ECE may also have influenced the situation. I knew six of 12 interviewees in some ways beforehand which may have affected the interviewing situations as well. The interviews and their locations were scheduled according the timetables of the participants: eight interviews were held at the work premises of the participants, two at ECE premises, one at my home, and one at participant's home because of very tight time schedules. The approximate length of one interview was 50 minutes, and the lengths varied from minimum of 33 till maximum of 76 minutes.

I recorded the interviews with a digital voice recorder after acquiring the prior consent from the participants for the recording (see Figure 6). After the interviewing sessions, digital files were transcribed into verbatim data, which consisted 153 pages of material. I transcribed the first two interviews (33 pages) myself, and the remaining ten interviews were transcribed by an external Finnish company specialised in research support services. Due to trustworthiness in narrative approach, I sent first the transcribed interviews and later on, individual narrative stories by e-mail to the respondents in order to let them give feedback or possible corrections to their own data. Eleven of the twelve respondents were in contact to me, and altogether eight persons sent some minor corrections and comments either to the transcribed text or to their narrative stories. The corrections were typically requests to change or remove a few words or sentences from places where an external reader may have recognised the person in the story. When integrating the stories into the entire study, I changed the real names of the respondents into pseudonyms. According to my supervisor's advice, I chose the pseudonyms from the history of electrical engineering, and partly from the history of mathematics and physics. The names selected for the persons in the stories are included in the introductions of each narrative story.

Figure 6. *The interview process (author's original diagram)*

As a whole, the interviewing process took approximately three months; from late May to June in 2008, then continued in September and lasted till the beginning of October in 2008. Due to the Finnish holiday traditions most people had their summer holidays from midsummer till the beginning of August during which no interviews were completed. It was not possible to complete more than two interviews per one day. First, it was rather demanding as a process for the interviewer, and second, due to logistical reasons. The geographical sites of the working places of the respondents set some constraints on moving from place to place in the capital region.

After I had received the checked interviews back from the interviewees, I started forming the narrative stories. I read the texts repeatedly, which was very slow. As the language of the dissertation study is English, I began to reconstruct the narrative stories into English, which was furthermore rather slow at least due to the differences between Finnish and English languages. During the reconstruction process, I needed to consult many colleagues several times by asking them English equivalents for complicated Finnish words, mostly in the engineering domain. As one example of the challenging words, I could mention is: "*moottorin pitkittäisleikkuri*" in the field of electric drives, which translates to *'a slitter re-winder'* in English. The major difficulty was to

be able to translate colloquialisms in a way they could be clearly understood in the stories. The Figure 7 describes the process of writing the narrative analysis:

Figure 7. *The process of the narrative analysis (author's original diagram)*

After the quantitative data collection phases, collecting interviews was very rewarding and inspiring. Furthermore, I had used this form of data collection several times in earlier research which made the process more flexible. As a researcher, it was also very exciting to observe that the respondents highlighted the same type of phenomena which emerged in the surveys. However, the interviewing questions were rather open, and did not steer the subjects to answer in any expected way. When I consider further possible research topics, I would continue with the qualitative approach, especially with interviews, when aiming to reach deeper knowledge on a particular theme.

4 Results

This part of the study is divided into four different sections. The results of the research are documented chronologically according to the time period each phase of collection was completed. The first and the second sections delineate the survey data collected in years 2006 and 2007. The data collected were both quantitative and qualitative. The section 4.3 consists of the qualitative narrative stories which I formed of the interviews gathered from May 2008 to October 2008. The section 4.3 and its narratives form the most significant part of the results. I have introduced the main findings of the qualitative interviews in the section 4.4. The summary and analysis of all the results are presented in Chapter 5 (Summary of the results).

4.1 Results of the first survey

In the results of the first survey, I focus on the findings which describe the connection between current job of the respondents, and their earlier studies at TKK. The work experience of the respondents in years is described in Table 4. The largest part of the respondents was born in the 1970's. The respondents had graduated within few years ago from the time the survey data were gathered and most of them had gained from one to five years of work experience. In that phase, shortly after graduation, it is probable to be able to reflect well on the quality of studies and the time spent at TKK. The relation between the theory and practice could also be better reflected.

The respondents in the sample group of graduates had been satisfied in overall with their studies; the respondents answered that they had been taught rather well (59%), or very well (7%) at ECE (see Table 7). But when I asked on the study guidance, their opinions varied somewhat more and, for instance, 10 respondents out of the whole sample stated that they had needed no study guidance. They had received guidance far and away from their peer students (75%), and half of them mentioned having received guidance from professors and teachers. Additionally, one fifth of the sample told that study counsellors and student tutors (*isohenkilö* in Finnish) had given them guidance. Only nine respondents (7.5%) answered that had asked study guidance from planning officers from the ECE's study administration.

Electrical and communications engineering was taught at ECE (n=99)	
	%
very well	7
rather well	59
not well not poorly	19
rather poorly	13
very poorly	1
Received guidance to studies (n=99)	
	%
always	9
rather often	25
often	23
seldom	26
never	6
did not need any guidance	10

Table 7. *Satisfaction in the studies and in the study guidance at ECE*

The answers showed that a rather large part of the respondents thought that their current job was very well or rather well related to their studies at ECE (see Table 8). They also thought that their studies had been useful at work very much or rather much (together approximately 72% of the respondents). These findings could indicate that graduate engineers were satisfied with their studies and could integrate their studies to the working life in general. Furthermore, the findings could indicate that they had gained scientific knowledge during their education, and their scientific thinking had been developed. The Likert-scales used in these questions were as follows: 1=very much/very well to 5 = very little, or very poorly.

Summary of major questions in the first survey	N	max	min	mean	s.d.
Interested in nature sciences when starting studies at TKK	99	1	5	1,64	0,81
Interested in electrical engineering when starting studies at TKK	99	1	5	2,00	0,94
Satisfaction with education of electrical and telecommunications studies	99	1	5	2,41	0,85
Electromagnetic studies' relation to other studies at Dept of Electrical and Comm.	99	1	5	3,27	1,16
Could use electromagnetics studies in other studies	99	1	5	3,52	1,15
Current work related to studies at Dept of Electrical and Comm. Eng.	99	1	5	2,54	1,23
Electrical and telecommunications studies have been useful in work	99	1	5	2,17	1,06
Electromagnetics courses have been useful in work	99	1	5	3,69	1,24
Gained scientific knowledge during studies at TKK	99	1	4	1,84	0,88
Scientific thinking developed during studies at TKK	99	1	4	1,76	0,73

Table 8. *Summary and results of the main questions in the first survey*

In the first survey, I also sought answers to how the graduates' professional socialisation had taken place through electrical engineering education. This part of the research I performed in co-operation with Dr. Miia Martinsuo from the Department of Industrial Management who designed the factor analysis with SPSS. Exploratory factor analysis (principal components analysis with varimax rotation) was performed for all the questions items on professional socialisation and satisfaction in order to uncover basic variable structure. A part of questions were removed during the analysis due to their poor fit with the model. The questions (listed in the Table 8), total 11, were included in the final model. The data were appropriate for factor analysis. Four factors had an eigenvalue over 1, and the four-factor model explained 71.5% of the variance in the variables. The variable structure, reliability coefficients, factor scores, and the expected logic between the variables are presented in Figure 8.

The model exposed three variables (see Figure 8). Each covered an explicit aspect of professional socialisation perceived by the graduated engineers. The three variables were: 1) technology adoption, 2) scientific thinking, and 3) professional benefit. Technology adoption focused on graduates' perceptions to see the benefit from electromagnetic studies. The second, scientific thinking, concentrated on the graduates' interest in scientific issues. The third variable, professional benefit, centred on the benefit which graduates had received from the university studies to the current professional life. In the Figure 8 there is also a fourth variable Satisfaction with teaching included in the model. Due to its rather poor internal consistency (0.54), it may reflect difficulties with the questions in the survey and thus was not considered equally with the three others. The results show that satisfaction with engineering education may explain parts of professional socialisation, in particular through fundamental and holistic knowledge in the form of technology adoption and scientific thinking. Conversely, the outcomes of this sub-analysis showed that in order to reach professional benefit from engineering education, it is essential to view other perspectives to socialisation than the one of education. (Keltikangas and Martinsuo 2009.)

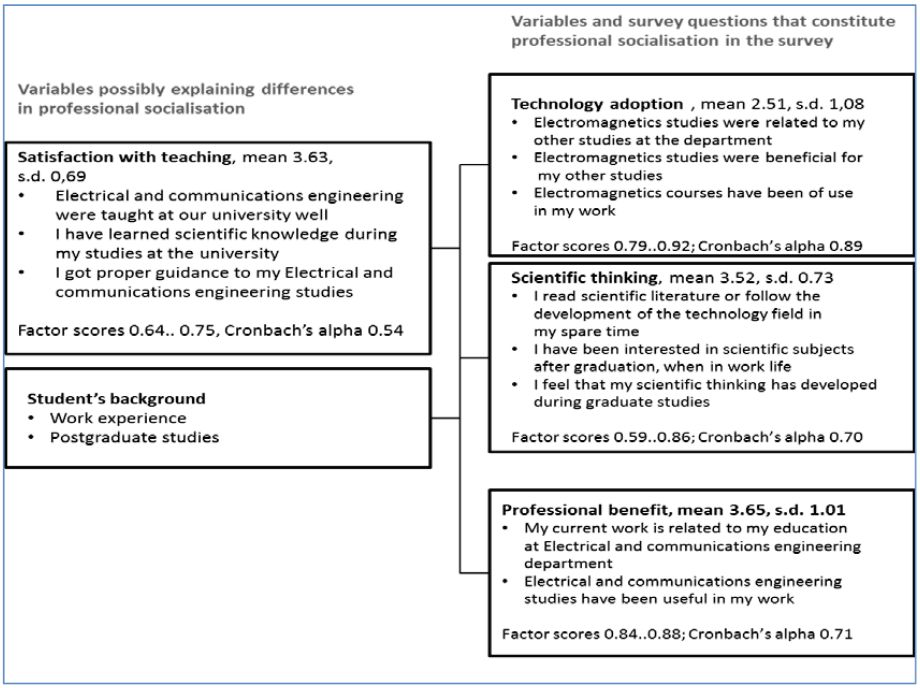


Figure 8. *Framework of the professional socialisation in particular in electromagnetics education (Keltikangas and Martinsuo 2009)*

The respondents in the first survey had also a chance to answer some open-ended questions that prompted for the explanations of their responses. The question, to which an open, qualitative answer was connected, was 'I have felt that courses on electromagnetic theories have been of use in my work'. If the respondents had chosen an option 'rather little' or an option 'very little', they had a possibility to explain and prompt their answers. Most of them answered that their current field in engineering was very different from the substance of electromagnetics. They had worked, for instance, in the telecommunications product development. Some of them mentioned that the theories taught during the field theory courses were rather hard to integrate into the practice. However, most of them believed that learning electromagnetic field theories had formed their general engineering knowledge, or foundation. (Keltikangas and Wallén 2010.)

In general, the first survey was a starting point for me to the entire research process. Afterwards, as an evaluation, I can recognise many parts of the research process which could have been performed better, including the design of the survey structure and individual questions with respect to the quantitative analysis approach. However, the first survey served its place in order to cover the field and phenomena possibly rising up from it. Secondly, it was a

sort of pilot study because surveys in particular on electrical engineering education were not much performed before. In general, when I regard this as the process of growing as a researcher, I could find it very useful, in particular when charting those areas in which I needed to cover as a researcher.

4.2 Results of the second survey

4.2.1 Quantitative results of the second survey

The sample group in the second survey consisted of students with delayed studies in electrical engineering. The respondents in the second survey (n=120) completed a survey with both quantitative and qualitative question items. The quantitative part was similar to the one in the first survey, excluding two new quantitative questions on professional competencies, which were added into the second one. The main questions items with their averages and standard deviations have been collected in Table 9. In general, the averages in comparison with the ones in the first survey were somewhat lower. The respondents were generally satisfied with the teaching at TKK (mean 3.42), and thought that their scientific and engineering thinking had been developed during their studies (mean 3.92). The substance of field theory courses were regarded in general difficult, the courses had demanded more work in comparison to the other courses, and the substance of them were not found very useful in working life. However, most respondents in the additional answers mentioned that their jobs were in such fields where the substance of electromagnetic field theories was not needed, for instance, in telecommunications field.

Question	Students with delayed studies (n=120)	
	mean	sd
1. Electrical and communications engineering was taught at TKK [scale between 1-5 from very poorly to very well]	3.42	0.83
2. My scientific and engineering thinking has developed during my studies at TKK [scale between 1-5 from very poorly to very well]	3.92	0.91
3. My electrical and communication engineering studies have been useful in working life [scale be-	3.37	1.25

tween 1-5 from very poorly to very well]		
4. The field theory courses have been useful in working life [scale 1-5 from from very little to very much]	1.82	1.08
5. I could use the contents of the field theory courses in my other studies [scale 1-5 from from very little to very much]	2.04	1.13
6. The field theory courses were [scale 1-5 from very easy to very demanding]	3.84	0.74
7. Compared with the other electrical and communication engineering courses, the amount of work for the field theory courses were [scale 1-5 from very easy to very difficult]	3.72	0.66

Table 9. *The summary and results of the main question items in the second survey*

In addition, the respondents evaluated the importance of 19 different professional competencies or qualifications concerning their own job, or their own field or substance (see Table 10). In the latter question, the respondents assessed in which context they had adopted the competence or the qualification in question. The scales in the two questions on competencies were from 1 'not all significant' to 6 'very significant'. Furthermore, there was also a possibility to answer 'not able to reply the question'. Competencies chosen to the questionnaire were based on the results of the first survey, and partly adopted from the study by Mäkinen and Olkinuora (1999). Likewise, they were based on the basic character of engineering education. These competencies also represent typical ones needed in engineering field, and also based on the prior research referred in this study.

The averages of all competencies assessed are listed in the Table 10. The scales were from 1 [not all important] to 6 [very important] included with a possibility to answer 'cannot answer'. The majority of the respondents completed all the sub-items in the question. Problem-solving skills, knowledge of own field, information management, systemic thinking, and critical thinking were assessed with the *highest* averages by the sample group (see Table 11). Most of these competencies listed in the question are such which have not been explicitly mentioned in the engineering curriculum, or in the course descriptions included in the study guides. On the contrary, these competencies have so far been randomly or tacitly integrated into the engineering courses. This integration has depended on the teacher in each course. Over-

all, however, it has not been systematically completed in the degree programmes, or in the curriculum design.

Descriptives of the competencies assessed in the second survey (n=120)			
Competence	***N***	***M***	***SD***
knowledge of own field	120	5.32	0.93
social skills	120	4.77	1.04
group and networking skills	120	4.82	0.98
computer skills	120	4.93	0.91
general socio-cultural knowledge	119	3.88	1.19
self-assessment	118	4.63	0.99
critical thinking	120	5.03	1.01
applying theory into practice	119	4.75	1.11
systemic thinking	120	5.29	0.86
problem-solving skills	120	5.45	0.77
innovativeness	119	4.76	1.09
independent working skills	120	4.99	0.88
scientific thinking	120	4.03	1.25
theoretical analysing	120	3.86	1.33
information management	119	5.31	0.82
oral communication skills	116	4.60	1.18
written communication skills	118	4.72	0.96
effective learning skills	119	4.91	0.94
abstract thinking	119	4.52	1.16

Table 10. *Descriptives of the competencies assessed in the second survey*

The top five competencies (n=120)	
Competence	*Mean*
problem-solving skills [C1]	5.45
knowledge of own field [C2]	5.32
information management [C3]	5.31
systemic thinking [C4]	5.29
critical thinking [C5]	5.03

Table 11. *The top five competencies assessed in the second survey*

General socio-cultural knowledge *(M 3.88)* and theoretical analysing *(M 3.86)* were assessed lowest of the given choices in the question. Likewise,

social skills *(M 4.78),* group and networking skills *(M 4.83),* self-assessment (*M 4.63),* innovativeness *(M 4.77),* oral communications skills *(4.62),* and written communications skills (M 4.72) were all valued clearly under the numerical value of five. Scientific thinking *(M 4.02)* was also evaluated quite low compared to the top five competences. Effective learning skills, which should form the basis for learning new competencies and lifelong learning, were not valued very high (*M 4.91*).

In the second question the respondents assessed where they had learnt the aforementioned competencies (see Table 13). The Likert-type scales were used in this question as well, with scales of 1 to 5 (1 = learnt at work, 2 = at university, 3= combination of 1 and 2, 4 = elsewhere, 5 = in free time activities).

Table 13 describes the frequencies and percentages of the given answers:

Top five competencies: where the respondents have learnt them					
	f(%) ***C1***	***f(%)*** ***C2***	***f(%)*** ***C3***	***f(%)*** ***C4***	***f(%)*** ***C5***
at work	35 (29)	29 (24)	12 (10)	50 (42)	12 (10)
at university	24 (20)	30 (25)	24 (20)	16 (13)	35 (29)
combination	43 (36)	56 (47)	56 (47)	36 (30)	35 (29)
elsewhere	7 (6)	*na*	6 (5)	10 (8)	16 (13)
in free time	11 (9)	5 (4)	22 (18)	8 (7)	22 (18)
total	120	120	120	120	120

C1 = problem-solving skills
C2 = knowledge of own field
C3 = information management
C4 = systemic thinking
C5 = critical thinking

Table 12. *Percentages of where the respondents of the second survey had learnt professional competencies*

Regarding all five choices, at least every third respondent had chosen the combination of learning at work and at university. It was astonishing that the respondents replied that they had learnt information management (18%), and critical thinking (18% as well) in their free time. It could be presumed that younger generations of students have learnt and experienced a different type of media culture with computers and, for instance, seek easily information in Internet. New generations which enter higher education, are in-

creasingly digital natives with good virtual networking skills and very well acquainted with various forms of social media (Prensky 2001).

Furthermore, this particular survey question included a possibility for giving non-exact answers. It may be difficult to evaluate where exactly a certain competence could have been adopted. In practice, the alternatives where competencies had been learnt, were too ambiguous and did not support answering properly to this question. For instance, the alternatives 'elsewhere' and 'in free time' were too unclear and overlapping. On the other hand, engineering students may not be so familiar with this type of assessment questions. Also, regarding learning styles and reflection on one's learning, it may be assumed that the respondents of this survey have not received sufficient skills for this type of learning assessment during their studies at the university.

One of the background questions for the students in this group concerned reasons why their studies had been delayed (see Table 14). A large body of the students (70%) in the second survey were working full-time, and only ten participants (8.2%) were full-time students. The question for the delay reasons consisted of different options to choose: guidance of studies (lacking or not sufficiently), motivational reasons, difficulties in learning, difficulties in time management, working part-time or full-time, challenges in choosing right courses, economic, family, or health reasons. The majority of the respondents chose at least three to four options. The assumption is that the selected ones were intertwined. Furthermore, they may be rather complex, and not straightforward to reflect which has caused the study delays in the first place. However, even more significant is that the university should develop means of getting in touch with these students, and activate them back to the studies. In any case, the sample group chosen for this survey had 80 study weeks or more, and these students could be expected to complete their entire Master's degree.

The three most significant reasons for the study delays were:

Three main reasons for the study delays (n=120) Frequencies and % of the respondents	
part-time or full-time working	84 (70%)
motivational reasons	73 (61 %)
difficulties in time management	46 (38 %)

Table 13. *Three main reasons for the study delays (respondents of the second survey)*

4.2.2 Qualitative results in the second survey

The qualitative answers given in the second survey showed that most respondents were aware of the demands of the information society. Furthermore, they were also quite aware of the requirements and challenges of knowledge-intensive work. The majority of the respondents mentioned information, knowledge, or its creation or processing in some ways in their open-ended answers. Learning skills and their development were rarely mentioned. However, learning in general was mentioned in different forms.

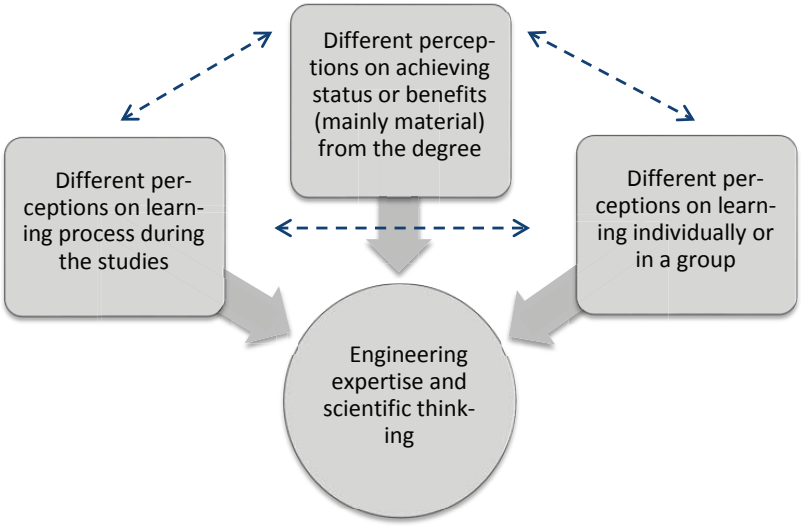


Figure 9. *The qualitative categories found based on the qualitative data in the second survey (author's original diagram)*

As a result of the analysis, I formed three different categories (see Figure 9) based on the collected data with content analysis method (Krippendorff

2007).The first category is named as a **learning perception category**. According to the analysed data, this category divided engineering students' perceptions most. Only a small minority mentioned lifelong learning, continuous learning, or learning in general as a means for maintaining expertise, competencies, or skills. Also, this minor group of respondents could identify daily work tasks as a way of learning. However, learning to learn should be a key competence in a knowledge-intensive work profile. Even fewer respondents mentioned collaborative learning as a common or recognised way of learning, for example, sharing novel knowledge in working places. Some commented that engineering expertise can be continuous learning. However, the perception of learning was tacitly hidden in their opinions; they mentioned that their studies at TKK were not sufficient. The studies had offered the foundation; they had to grow gradually as experts at work. The following examples describe the first category:

"[it is] continuous self-development and tasks which demand learning new in which no one ever will be perfect, but when striving to that will help performing in your daily tasks" R11

"[it is] the fact that you have basic knowledge in several different domains. This enables a complex problem-solving ability in a situation in which practical knowledge is not enough anymore. An expert in technology does not necessarily know everything, but s/he has abilities to learn quickly the knowledge needed in the profession." R12

"[it is] updating your own skills continuously, that is continuous learning. You have to tackle new knowledge and ideas with enthusiasm, and study them at least in general level, in order to follow the development" R39

"Engineering expertise at its best is diverse learning, developing and knowledge in a dynamic work environment. Engineering expertise requires also competencies in business and social skills." R59

The second one can be named as a **status or value (or benefit)** category. In this category, there were clearly two types of respondents: those who regarded engineering education and a Master's degree in Engineering as a means of achieving something of merit or benefit in their lives. Several factors were named: a better job, better salaries, work possibilities abroad (outside Finland), better chances to achieve a more respected position. One respondent even mentioned a possibility achieving "a beautiful wife". These respondents very seldom mentioned the connection to the first category, the concept of learning.

The latter part of this group regarded engineering education as a way to better understand the society, links to other scientific disciplines, colleagues at work, or to the work context itself. This group had a more systemic and holistic approach to engineering expertise. In Western European countries, people tend to emphasise material and secular values of life instead of immaterial or intellectual ones. This obviously is reflected also to engineering students and their perceptions. Engineering education in Finland is, to some extent, renowned as promising a good, well-salaried career with a high social status. A part of the students may use this as a criterion when choosing and applying for a place to study. Persons in the latter group mentioned that engineering expertise is very important or essential for the whole society. This category is to a certain extent related to the areas which Martin et al. (2005) has presented (the science and practice of engineering). The following three examples describe such respondents who may regard engineering expertise from the status or beneficial viewpoint.

"[it is] an asset in the future presuming that you can build a reasonable study programme. Studies chosen 'wrong' may make your job finding more difficult, or at least they do not make it easier." R20

"A significant professional skill which is less appreciated in Finland compared to other European countries. Engineering expertise is an important factor when filling up jobs" R62

"Personally makes no difference to me. In practice the only reason why I even try to graduate is that it may open doors which are not open now (for instance working abroad in the future)." R63

The following excerpts define such respondents viewing engineering expertise more holistically, and with links to other areas.

"Has to be based on a wide outlook of own branch before you can go deeper into the details of your own field of expertise. You must be able to see connections between different issues, also outside the technical field" R55

"[it is] continuously developing expertise harnessed to various needs in working life. Engineering expertise is at its best versatile learning, development and knowledge in a dynamic working environment. Engineering expertise requires dealings with economy and socially." R59

The third category divides the respondents also into two smaller groups. It is named as an **individual vs. collective** category. This category is intertwined with the two aforementioned categories. Its name relates to the connection of the respondents to his/her surroundings or individual context. In

this category those having a collective perception, could perceive links in both questions to their colleagues, clients, work environment, or society in general. Some of these respondents mentioned that expertise is sharing knowledge, or an ability to communicate with others and guide them. Those respondents, who had a somewhat materialistic perception of expertise and scientific thinking, may be categorised in the individual category. The following quotations represent this category from both viewpoints. The first one is an example of a collective thinking category:

"[it is] using knowledge and competencies in your daily work. It is an ability of analytical problem-solving with others." R44

The following quotation describes the individual thinking category:

"[Scientific thinking is] essential for making a good career. According to my opinion, the best way to become an expert is to focus on an interesting field so that you control it really well. Besides, becoming an expert requires continuous interest towards the selected field, and you must be able to update knowledge to keep up with the current development." R75

Additionally, a minor part of the respondents belonged to a "critical" group according to their answers. However, a fourth category was not formed of them because the number of these respondents was not so large. These respondents had critical attitudes in toward the studies at the Faculty of Electronics, Communications and Automation. In particular, the answers to the question "Scientific thinking is..." included much criticism towards the curriculum and teaching at the faculty. According to their perceptions, scientific thinking could not be developed at TKK, or during their studies at TKK. Some of the respondents mentioned other courses at other departments or faculties at TKK where they expected better possibilities to learn some fundamentals of it. Most of the respondents in the entire sample group believed that scientific thinking skills could be something which is not needed in daily working life, but only for researchers who have chosen the scientific career. Only very few people of the entire group had answered that creating scientific thinking skills is one of the aims in higher education.

Most respondents mentioned the following competencies or abilities belonging to engineering expertise and scientific thinking. Many of them were mentioned as answers to both questions:

- Analytical thinking
- Problem-solving skills

- Critical thinking skills
- Ability to search information and create new information
- Ability to observe links between different fields of expertise, and outside the technical field
- Integrating theory into practice

Factors as age, or the length of work experience did not have much effect on the answers, or on forming different categories. A rather young respondent (from 26 to 29 years old) could have wider, holistic perceptions of society, or of the development of one's expertise. However, middle-aged respondents (40 years and over) did not all belong to the group with many years of work experience. My assumption is that this sample group of engineering students with the delayed studies is rather heterogenic, and further research would be needed in order to gain further knowledge on their perceptions and thinking.

The qualitative data collected in the second survey served as a base for the next phase of the research when designing the interviews. The next section consists of the narrative stories which were collected with semi-structured interviews.

4.3 Narrative career stories

I collected qualitative interviews which I turned into narrative career stories according to Mischler (1995). These stories form the main proportion of the results of this study. All narrative stories have been formed with the same structure divided into same time periods. The questions in the interviews followed the time line of the life of respondents: 1) the time before starting studies at TKK, 2) the time of studies at TKK, 3) working as graduate engineer, and 4) finally the future; how the respondents saw their future concerning their work career and its development.

The narrative stories were formed following these time lines. All the persons interviewed in this study have received a pseudo name in the stories. These names belong to famous scientists in the history of electrical engineering or physics. This idea was from the thesis supervisor and researcher colleagues at one study meeting when I processed the stories.

The following abbreviations were used in the quotations selected of the narrative stories:

I	interviewer
R	respondent
ECE	the Department of Electrical and Communications Engineering (current Aalto University School of Electrical Engineering)
TKK or Poli	Former Helsinki University of Technology
[xxx]	added notes and explanations in the quotations by researcher
xxx	emphasised word or expression in the quotations by the respondent

4.3.1 Industry or private-sector oriented work narratives

The respondents in this sub-group represent the industry-oriented electrical engineers. They had all been working in the industry at least 10 years or more. In the engineering context and in this study, industry consists of companies or enterprises functioning in the private employer sector, not merely industrial plants. Usually, such expressions as "engineering graduates receive a job in the industry", or "universities are training engineers for the industry" are used in describing this. Furthermore, a typical expression used is that engineering students at Finnish higher engineering education complete the Master's thesis "in the industry" at a salaried work. A few respondents in this sub-group had worked as a researcher at TKK after graduation before changing into the industry. However, when working some time as a researcher they could discover that they themselves preferred a different type of career or tasks, for instance, tasks in sales, marketing, production planning, or in general management. Later on, they moved working into the industry.

The first interviewee in this sub-group was Thomas. Regarding these persons as 'types', he could be regarded as a 'salesman' based on his own career choices. Considering the typical career choices, choosing sales tasks is not very popular or common among engineering graduates. This first respondent was named after *Thomas Alva Edison* (1847–1931), an American inventor and a scientist.

Thomas

The time span before the studies at TKK

Thomas had acquired influence and role models in childhood from his home his father being an engineer. Furthermore, Thomas added that he had good friends in school and in his childhood, who were very interested in the engineering field, in particular, in computer science and computer programming. He revealed that his friends had lured him to the computer world.

I: How did you get interested in technology as a field?

R: Well, it probably came inherited from my father because he is an engineer and he succeeded in creating my interest to technology. Then I had some friends who were really good with computers, they lured me into these computer 'things', you might also know them [laughing].

Thomas had clear plans when choosing the study field. In the upper secondary school he had considered selecting between medicine and engineering but decided to apply to TKK. He had quite clear thoughts about these both fields.

I: Could you please tell more closely when you got the idea of applying to TKK and engineering?

R: Yes, it was along in the upper secondary school when I thought I might choose medicine [as a field] to be good but I can remember that kind of thing that in some phase I wondered that this engineering is easier – when you blow, then the target [not a human patient] is very silent, but you blow as a [medical] doctor so then the target [a human patient] starts to yell, or at least the members of the family start to yell, either way, so that's how I thought this [engineering] would be a good branch.

In addition to his thoughts in the upper secondary school, Thomas admitted that he had a kind of systematic career choice thinking when choosing electrical engineering. At the time he was applying to TKK, it was more popular to apply either to computer science which was at that time a part of the Department of Electrical and Communications Engineering, or to the Department of Industrial Management. Explaining these trends in applying, he expressed his thoughts as follows:

R: The reason why I went to ECE that I had particular a career choice thinking. At that time, electrical engineering was not so popular. So, when I applied [to the university], computer science or industrial management were among the most popular ones – so I thought that so called God's best grain went there [...] and so I expected that in these more traditional engineering fields you could find your own niche easily. And then this Nokia phenomenon [the rise of Nokia as a company] came 'out of the blue' but that came luckily in the beginning of 1990's so that [Nokia phenomenon] increased the value of electrical engineering studies."

The time span during the electrical engineering studies at TKK

Thomas decided to complete his studies at ECE fast and strategically from the very beginning. He described his time of studies with an expression "fast and dirty", and also said that he was a kind of a "lone wolf" as a student. He did not participate much in the student free time events; partly because he originated from the Finnish capital region [where the university locates in] and was living at his parents' home and partly because of his prior choice to study more individually. He also expressed that he had financial causes to complete his studies faster. He chose in purpose the way to pass the courses fast in order to save time; he mostly went directly to the exams, without participating in the voluntary lectures or practices. He told that his aim was to pass the courses, and not to think about which type of grades he would receive. However, he added that he did not receive poor grades either. Mostly his average grade was three [scale being from 1 (poorest) to 5 (best)]. Thomas told that it was easy to motivate oneself to the substance of each course, even though rather regularly the substance was quite often abstract.

He described that the studies at ECE gave him a good overall framework of the field. However, he added that he may have not received very detailed knowledge. He mentioned electromagnetics as an example; he pointed out that if somebody asked him something about static or dynamic field theories, he could understand in general *"what the person is talking about"* or could fetch more information about the substance if needed.

The time after graduation to the moment of the interview

Thomas graduated from TKK in year 1991 (see **Figure 10**). He completed his Master's thesis in the industry and was already in working life some years before his graduation. One significant phenomenon behind his choices and career was a deep recession period in Finland which began with the national

bank crisis in 1989, and continued at least during the years 1990–1995. Thomas entered working life concurrently, and this larger phenomenon affected his choices and career expectations as well. He had acquired a type of systematic decision making when applying his first permanent job. In addition, he had a clear vision of three different career choices in the telecommunications branch which were the following:

- Career in product development with a deep knowledge and expertise of the specified field
- System specialist with interface design and black box viewpoint [knowing what a system does, not how it does it]
- Career as a sales person

Thomas had reflected on the three choices carefully and decided to take the third one. He saw sales career quite unpopular among graduate engineers at that time and he even thought that he himself was not an appropriate person for sales career. However, he took an optimisation strategy in order to receive a vacant job. He describes his thoughts about decision making as follows:

R: But then I saw that this [choosing sales career] would include a challenge and this would offer a real possibility to differentiate you in working life. And I felt that if I will learn this [sales career] and this is really difficult for me, then everything else will be easy. And that's why I went into this, and I believe that I got my first job because in the interview they asked me 'what would you like to do?' and so then I said that 'I would like to go into sales' so those people [interviewing him] were quite dumbfounded and asked why would you like to be a salesman when everyone else wants to be a technology specialist. Well, then I just said that I want to be a salesman, and maybe that's why I got the job [with that employer] which was in a large American company. There I went through their training systems and learnt this sales job. So, I can see this [career choice] as a very conscious decision of mine. The normal way how it goes when I have spoken with colleagues that today the salespersons have systematically started as technology specialists and then, let's say, after 10 years moved into a pure sales job. With me it has gone the other way round – I started as a salesman and then moved more and more towards a technology specialist.

In the time of the interview, Thomas seemed to be still quite content with his own choices in the beginning of his career.

The larger phenomena in the career of Thomas

Thomas received his first working place at a telecommunications company which among others in that branch was in the beginning phase of the sales

processes. Furthermore, Thomas mentioned as a remarkable thing that in year 1991, the world of telecommunications markets was just to be opened. He mentioned that there were a few people in the teleoperator company's management who had started their career in the manufacturing side. They could see the significance of sales and wanted to reverse the traditional way of thinking in the telecommunication business.

Thomas added that in the beginning of 1990's, among all graduate engineers, employers in this field respected most those who had studied at TKK. He described the respect as follows:

R: When you are at a certain level in the [telecommunications company] organisation so you do have to have academic 'papers', and of those all academic 'papers' the best ones are TKK engineer's, and of the TKK engineer's the best are electrical engineer's papers. But this is currently changing; especially North American owned companies don't care a bite. But earlier in the 1990's it was different.

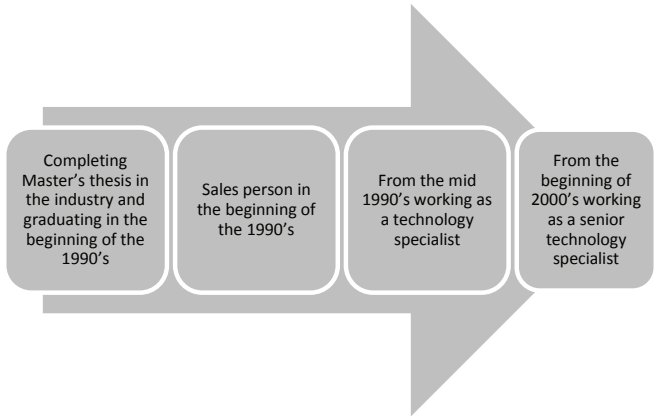


Figure 10. *The career path of Thomas (author's original diagram)*

He has developed his career since he graduated from TKK. His work role has been quite independent and he has been working with all types of clients during his whole career. He described that learning has always been a part of his job; especially learning individually. His employers have expected him to learn the new substance needed in the new client projects. He explained that the employer provides employees with all kinds of material in order to learn the new knowledge themselves. Thomas adds that he has received a basic framework or construction in engineering at TKK in order to build new knowledge on that.

R: Then in practice you start building up more and more pieces on the basis, and then you always build more and more, piece after piece. And those facts you have learnt sometimes at Poli [TKK] are hidden there under the pieces but from somewhere you have to start to build it --- But I see it so that there is a such basic framework [of knowledge] that when you have a certain case then you can locate it to a certain area and start to 'drill' deeper into the case --- A year ago I got a new client project in which I had to learn SS7. SS7 is a kind of communication protocol with which switching centres discuss with each other --- that is a totally different world there, and it was the area of Rahko [emeritus professor at ECE] which I did not have interest in [not Thomas's main subject] but I was there in the side of Halme [late emeritus professor at ECE]. However, I had some kind of faint idea about it so then it was much easier to start to study it [the SS7 communication protocol] --- In this field, you have to build it [domain knowledge or expertise] constantly.

Thomas continues that his image of the work and the roles at the work have remained about the same. However, the substance is changing all the time and he has to learn constantly new knowledge. Then he admits that *"of course one day comes the moment when you forget more facts than you can learn new ones, and unfortunately we are facing it anyways"*. But, however, he defines his work field as follows: *"well, this field is quite good because only few younger people are entering the business–how should I put it – there are not many young clever and fast learning [people] coming in – the competition is getting older with the same pace as I do – that makes it easier.."*.

The career path of Thomas has been described in Figure 10.

Definition of expertise and expert by Thomas

When I asked how to define expertise by using own words, Thomas defined the expression through outcomes or products. His long career with sales and clients apparently affects to a great extend his answers about expertise. Just before the interview, he had been to a course where expertise had been processed through a sales organisation view. Expertise was regarded as a pyramid model, and according to Thomas, it consists of several levels. He defines an expert through what the person is processing as a result of his/her work.

I: When you do not think about any levels, how would you define expertise in general?

R: If I could define it, I would do through what the expert is processing. Let's take the expert's client who uses his/her services. It can be either an internal or ex-

ternal client, and here we come to the idea of levels --- the relation can be such that the client is asking something from the expert and gets a response. And then we can move upwards to the next level in which the expert and the client are discussing together taking the subject forward---and then we have the next level in which the key word is "trusted advisor" [respondent is laughing]—in this level you are in a dialogue in which you are going forward like hand in hand together, it can be called a consultative relation. Another thing is in which area the substance is—is it very narrow and deep area which in certain cases is the right option, or is it then a wider, not so deep then it is, it can be a so called architectural approach. In general, what I have seen these, I take a kind of ageing example, I have a kind of a view that the career development models are based on the presumption that the traditional career development starts from this narrow and goes towards the wider. And easily a kind of small value reservation is added to this that the wider, architectural approach is better than the kind of narrower and deeper. But I would say that it is not always like this, that there are different types of roles [of experts]. ---

In expertise there is one thing that you are able to adjust your own expertise to client's situation — the client can be either internal or external and the experts can, they can adjust their own expertise to the client's situation which is the key issue. And if your expertise happens to match to the client's situation then you can manage with less amount of expertise.

The future and the most important aspects at work

The fourth and last phase in the respondents' life is the future focused on their career. When I asked the question about how Thomas sees his future in working life, he replied:

R: Well, when one wants to keep himself as a relevant worker, let's say you keep doing a kind of career plan all the time behind you, it's because you have gone through a kind of recession phase once, and the next recession can come whenever, or let's say, your employer can fall down [go into bankruptcy] the day after tomorrow, well, this is so that in these days these things are changing so quickly that all the time you try to build for yourself a kind of potential which you can use in plan B, and in the best case in this plan and in the plan A, and in that way you stay "valuable" – well, I have a kind of wretched viewpoint because I am a little bit afraid that at that day when your own personal "orange"[a citrus fruit, used as an analogy] has been drained, so you will be thrown to the dustbin [respondent laughing], so I think it goes like this… So it is better to keep your own orange fresh all the time [laughing again], and let's say, if something better happens, that's fine. But better be aware of this option"

As a summary, Thomas views his career as a salesman with a notion of expertise in technology. Economic trends have rather strongly affected his career choices and he has been able to forecast rather well the trends in respect to his own career. He sees expertise through the lens of sales world, and with the question of updating his competencies and skills, he believes in staying "valuable" from the labour market viewpoint.

In the next narrative story, the respondent comes from a more traditional branch of industry. Benjamin, the respondent, could be typed as a *traditional expert* in product development although along his career he has received increasingly tasks with sales and business. I termed this respondent according another famous American scientist, *Benjamin Franklin* (1706–1790).

Benjamin

The second interviewee from the industry was Benjamin who graduated from TKK approximately in year 1990. He has been working in industry since that with the same employer however having worked in several different jobs, also some years abroad in Germany. He has acquired approximately 20 years of work experience.

The time span before the studies at TKK

Benjamin had a traditional path before applying to TKK. He had always been good in mathematical subjects at school. He gathers that he started to think where to apply to study and about career in the upper secondary school. He considered that *"engineer's profession was a respectable one so it [TKK] was a natural choice to apply to"*. However, he said that he might have been more interested in history as a subject but he already thought at that time that it would not make as good profession as engineering. Benjamin applied at the same time to the Department of Electrical and Communications Engineering and to the University of Helsinki to study computer science. Finally, he found electrical engineering more interesting and he was accepted to TKK. He did not mention any relatives or friends as role models having studied at the same university, or in the engineering field.

The time span during the electrical engineering studies at TKK

When recalling how his studies had been, Benjamin said in general they may have gone better. He remembers one occasion from the beginning of his studies:

R: In the first beginning there was a, if I gather right, this kind of a general info [for the first year students] where this kind of thing was reminded to us that "you are all.." there were electrical engineering and physics' students present at that time, or maybe computer science students, so [tutors or teachers] noted that 'you have always been those pupils with [grades of] nine's and ten's, and in maths and in physics the best ones in your class, but here it will inevitably be so that a half of you will be worse than the average level". So [respondent laughing], that was a little shock in the beginning what was required there and how much more demanding it was [to study at TKK]. But then, maybe I learnt a kind of minimum energy principle how to pass the exams. --- Well, yes, I did notice quite soon that I was maybe not among the best [students] here anymore. But it was not a great shock to me, but the issue was that studying was not easy, I have to say that mathematical subjects are a kind of cruel - you have to understand them, otherwise you don't learn and you can't pass the exams.

Benjamin recalls from his study times that the subjects were not easy to learn. Language courses were easier, and he found them also so interesting that he took more of these courses than he expected in the beginning. He said that the teaching in those courses was so different in comparison with the teaching at upper secondary school. He recalls the circuit theory courses to be good and difficult ones, due to the excellent professor. He could say that circuit analysis was one of the most important parts of his studies in the beginning, and he told that he still has the course materials in the book shelf at his working place. He said that most of the studies in the beginning were either good and difficult, or not so good but still difficult.

In the end of the studies Benjamin started to think about applying a work place. During the studies he had had many summer jobs which were connected to his major subject. He had been working at a local electricity company, one summer in Germany in a multi-national electricity firm [AEG; Allgemeine Elektrizitäts-Gesellschaft]. Furthermore, he had received research oriented work experience at VTT and TKK. He completed his Master's thesis at the laboratory from which he graduated. He had been studying electric drives and power electronics as his major subject. So, it was a quite natural choice for him to apply a job at ABB (ASEA Brown Boveri). However, he emphasised the choice was much up to a chance. Furthermore, he stressed that the time

span he studied, affected his choices and situation. He studied mainly between the years 1984–90 which was the time for the great economic boom in Finland. There were several occupations available in the engineering field at that time. It was typical to study full-time for the first two years and then to have a part-time employment and simultaneously continue one's engineering studies. Benjamin states about that time as follows:

> *R: There were many jobs available during the time of studies. That was the typical way for technical students to study that time, maybe you studied the first two years full-time and after that you had to go to work. And of course, this lengthened your studies, but however, on the other hand, you learnt quite a lot all that kind of things which you don't learn for sure at school [at TKK]. So, such [a student] when graduating, who has actively worked during the studies, has a totally different position than the one who has just been at the school.*

The time after graduation in working life to the moment of the interview

Benjamin sees a clear connection between his studies at ECE and his career. He said that he has been working his whole career with the subjects he has studied. He does not see much difference with the area of his tasks when been just graduated and now [after approximately 20 years; but he has changed his viewpoint to his field many times] He mentions that he has not usually planned much about the future because *"in working life, the only definite thing is change but it is not daily, nor monthly nor yearly. You cannot plan much yourself when you work in the industry"*.

Benjamin describes his career path in engineering as varying, though not in showing a very fast upward trend. Still, he notes that he has mainly been quite content with his own path. He has worked in various production development and product maintenance, sales and sales support jobs during his career. He adds that in a sense he has acquired a somewhat exceptional career. Typically people after having been in a sales job do not return to the production development tasks. But Benjamin did so, and for the second time he has changed to the sales tasks.

He has had some major changes or transitions in his working career. The first one was when he changed from the production development into sales support. He mentioned the latter one was a quite different field. The second large change was when he was working two years in Germany in the end of

1990's. Furthermore, Benjamin adds that the third change was the return from abroad and going back to the product development tasks in Finland.

He claims that his working period in Germany was quite useful to him. He recalls the culture at working places to be somewhat different with its good and bad sides. Benjamin worked at the sales office there and could visit end customers and many factory plants. He tells that he learnt a quite trivial thing there that "*the world outside Finland is rather big"*.

I: Could you describe what things did you learn there abroad from the viewpoint of your work?

R: At least that trivial thing that the world outside Finland is rather big, and of course [something] which seems to be rather difficult to understand for some people that it [the world] is also rather big outside your own factory and meeting room—that you can decide about many things here and be very clever but then if the reality outside [your factory] does not agree with you, that is something significant. I could see that there. And of course that was such a convincing experience. It was also good in that sense that Finland is not really a rather large country nor TKK has a reputation of a very high quality university, but well, you could achieve some world leading technology with these studies--That you could well bustle around with them [with TKK studies].

Benjamin describes about his competencies which he has accrued in his career. In the beginning with this question he noted that it would be easier to say what he has forgotten during his working life.

R: Yes, well, it would be pretty easy to say that the things I have learnt at university, those I have just constantly forgotten, and then it is of course true that what I have learnt at work, that comes more and more, of course there are facts I have already forgotten.

First, he mentions the technical basic knowledge which he says he has partly received from his studies, but he has mostly learnt it in working life.

R: -- in general when you understand that if a motor runs and it is steered somehow so what is approximately happening there and how these parts of equipment have been built up and how do they function together with drives, load, power supply, and control, and what is happening in between there.

Second, Benjamin mentioned language skills. He has learnt to work fluently in English and in German, and he claims "*to manage*" with Spanish. During

the last year, the fields of business and contracts were novel in his work. Finally, he mentioned the basic knowledge in electrical engineering as a competence. Benjamin recalls it would have been better *"to learn it a little bit better- I could say that all those who study it would know that it [electrical engineering] is more important than you knew in the beginning, that also those very first courses [in circuit analysis], it would be good to learn them as well as possible. The only thing which comforts me is that everybody else has got the same situation. Maybe here [at ABB] now only every tenth [person] would manage these things well"*.

He would prefer to develop his competencies further in the business and contractual law because he assumed to be working in the job he has for some time in the future. However, he adds that it is somewhat difficult to think about developing his own competencies because of the unpredictability of the field.

Learning and further education at Benjamin's working place was not well organised or developed earlier. He used an analogy that learning something new was a little bit *"something like pushing somebody from a jetty into the water and then throwing a manual book "How to learn to swim" after you and to be told that so can learn to swim"*. When he receives new type of work tasks which he cannot perform yet, it is mandatory to learn them somehow, probably in one's own time.

Benjamin's career has depicted with **Figure 11**. Excluding a short period as an assistant at TKK before his graduation, he has worked during his whole career in the industry.

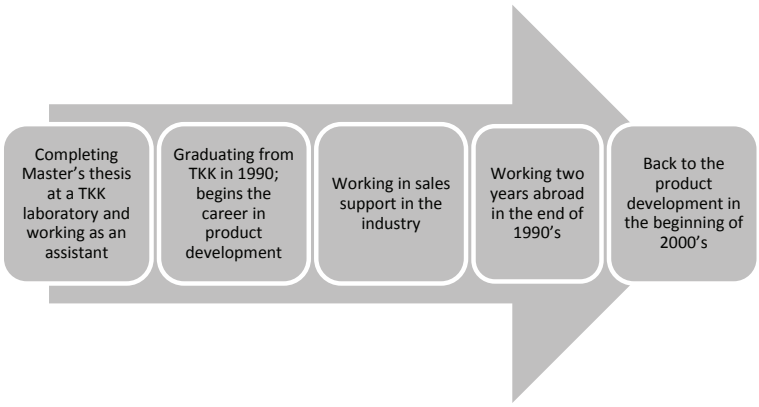


Figure 11. *Benjamin's career path (author's original diagram)*

Definition of expertise and expert by Benjamin

According to Benjamin, expertise is an ability and courage to say one's opinion about some subjects.

R: [Expertise is] when you have been asked a question how some issues are – then you must be able to clear up the issue and then precise and sure how the results are, and you must be able to document or report it in a form which is usable for those people who are doing decisions based on those results and they have also a clear view what uncertainties there are.

Benjamin's view on expertise relies much on engineering viewpoint or measuring and calculating. To him, expertise is to achieve a final result, the best possible one with the knowledge and time available and then to document or report it forward so that it is beneficial for somebody.

According to him, expertise is not to do research on something without reaching any results, but however to present all possible guesses and leave the responsibility [about the interpretation] to the reader. Benjamin mentions also that expertise is not avoiding to mention about uncertainties and to measure and calculate and make estimates and not to remember tell there are some uncertainties which can change [the results].

He ponders that possibly now different types of skills and competencies are appreciated in working life than before. Furthermore, Benjamin adds that organisational and managerial skills may affect much one's expertise. He also mentions basic engineering standards which are not enough in his current expertise. He listed which questions may have affected the demands or requirements of expertise:

- Globalisation (product development in various countries and co-operation and communication with the units)
- the changed toolset (in information technology) – mechanical design has changed including the computer programmes used in it
- purchasing components different and larger than before

The development of Benjamin's expertise as a path

Benjamin assumes that he has received a good basic knowledge and expertise from his studies at TKK but most of his expertise he has gained in working life and at work. He defines that he is currently in the expertise level in

which he can perform his tasks well, and he can well produce reports which is beneficial for those in a decision-making level. He continues that he is able to produce such knowledge in which the essential facts have been reported. However, according to him, his competencies in basic measuring or calculating, *"the raw technical work"*, has not developed much. He notes as follows *"maybe I have earlier been a better electrical engineer when it comes to calculating and such things"*.

The future and the most important aspects at work

When I asked about the most important aspects in his work, or in his career, Benjamin mentions earning wages: *"If you did not receive any wages, so then I would immediately go and search one [a job] where you do"*. Second, he mentions that he enjoys performing his work. He notes as follows:

> *R: Work takes a large share of the day and of the week, and if the work is very displeasing, then you could think is it worth doing it, and whether you are able to find such a job elsewhere which would be more interesting.*

Benjamin believes that he has succeeded in quite well in both of these aims. At the moment of the interview he estimated himself to be in the middle of his working career, not even in the middle because he assumed the general retirement age to be raised in the next 20 years in Finland. He sees that his aim in his career is to be able to develop him and to be able receive new tasks. Here in this phase, he tells a rather symbolic anecdote about his colleague at work:

> *R: It was absolutely fine; with us [at the office] we had an old generation's engineer who retired at the age of 65, so it was decided maybe about 1.5 years before he retired that we would need internet pages[first ones], so it was him who was leading the project. There is something a certain kind of style in that. So, if I could do something like that, then I would be satisfied too, that there would not be a day when I could not be ready to receive something new and to learn new [knowledge].*

Benjamin is an example of a graduate who has chosen, in particular, research and development in the industry as his career. He has been satisfied with his choices and also with the education he has received. However, in his career he has moved on towards more business-oriented type of tasks. As a type, he could be a mixture of R&D and business oriented engineer. Further-

more, he has received experience in working abroad which has affected his career, and provided him wider experiences.

From Benjamin, the stories move on to Sofia. She has also worked in research and development tasks. She has been some years off from the working life when staying at home with smaller children. This female respondent was named after *Sofia Kovalevskaja* (1850–1891) who was a Russian mathematician and a first female professor appointed in mathematics at a northern European university.

Sofia

Sofia graduated from TKK with radio science and technology as her major subject in the 1990's. She was thinking about choosing a research-oriented career, but after having worked some time as a research assistant at a research institute, she decided to change into the industry. After graduation, she has made her career in the industry in a global consulting company in the Helsinki capital region. She has acquired approximately 10 years of work experience excluding few periods of maternity leave.

The time span before the studies at TKK

Sofia had some role models for her career choices in her childhood as her father was an engineer. She recalls that when she was a younger child, her family lived close to a paper mill and she could visit steam power plants. However, she claims that she was not that much interested in technology as a child but assumes that her family background has affected her choices anyway.

I: Let's start, as the first question I would like to ask you how did you originally get interested in technology?

R: Probably a rather traditional [thing] was that my father was an engineer. I have lived in the neighbourhood of a paper mill, visited steam power plants as a child but I would not recall being that much interested in technology. However, the background in my childhood, I have lived close to engineers, even though my mother was not an engineer but still--.

Sofia recalls that she managed well in mathematics and physics and also went to a good quality upper secondary school in the Finnish capital region. When being at school she knew a few friends who were studying at the Department of Electrical and Communications Engineering and she learnt to

know about TKK as an option to study. However, when she thought back about physics at the upper secondary school, she says she hated the part of physics with electricity, and most of all, she hated waves and wave theory. She describes her experiences as follows:

> *R: Actually [when studying physics at school] I hated the electricity part in the physics, I could not learn it. Most of all I hated all of those waves and the wave theories and the final result was that I became a radio engineer. Well, I don't know was it about the nastiest things there [that she wanted to learn] or [because of ambition] but somehow I would recall that I would [have said] "oh, yes, I do want to go to technology" but one way or another, it [the thought] has been in me, as everybody [her family and friends] has assumed so and no one has been surprised [that she has chosen engineering as her career].*

She applied to ECE as a primary alternative but to make sure to receive a place to study, she also applied to the Faculty of Mathematics and Science at University of Helsinki. However, she recalls that TKK was her first choice and she did not seriously consider the other option.

The time span during the electrical engineering studies at TKK

When I asked about her study time, first of all Sofia mentioned student life with its various activities; guild activities, students' union and study affairs. In the beginning she was very enthusiastic about the studies but says that she was not studying so industriously though at that time. She mentions that she met her becoming husband during the first year of study, which affected her study activity. However, she claims that later on (after the few first years) she started to study more actively and more industriously. In the last year of study she was working in her major subject field outside the studies and completed her Master's thesis in the industry. Sofia recalls her study time that above all, at ECE she created and received a large network of friends and acquaintances that still exists.

As she recalled earlier, she disliked waves and wave theories when she started her studies at ECE. Another difficult subject for Sofia was the course in C-programming language. At that time she was struggling with it and was not at all motivated to complete the course. When reflecting on that experience, she notices that in those programming studies she has learnt analytical thinking and problem-solving skills. Though, she claims she could have learnt them from elsewhere, too.

R: So as I said before, when I came to ECE, I hated waves [electrical], and then there was another thing which was really difficult for me, was C-programming. I did it among one of the last courses [in the degree]. And I cannot count how many evenings I spent sitting at home, whinging why I should do this [course], I don't need this ever, I will never code, and then [in working life] I become an IT consultant or a coder. In a way, it's exciting, such a small course which created the base for that world but I think it is more, [it created] that analytical way of thinking and problem-solving, and in a way the means of doing things. However, I could have learnt it from elsewhere, too, it has not come merely from the electrical engineering studies.

Sofia's complete study time was approximately 6.5 years. Her final year of study was very intensive. She describes that time as follows:

R: But then supposedly a little bit later when I started to study actively [full time] so I really started to concentrate on the studies and other things, and then I was already at work, in my own field, and then I started to complete my degree. Yet, I studied 6.5 years and I could have time for the student activities. That year when I completed my degree so it was a kind of [intensive] year for me, first I graduated in February, then I changed my work to the current one in summer and then in the end of the year I got married so it has been a kind of [busy time]. But I have got really many networks and friends, if [I think about] the study time. I do not work purely in the field I was studying.[First] I was working as an assistant and then I was working as a part-timer and I was completing my Master's thesis in a very research-oriented job. I was not [in that field] at TKK but pretty close to it and I just noticed that I was nonetheless a researcher. Then I drifted into the consulting field and that is in a way [related to the studies] - that I do not have much [use] of those studies at the moment – Once in a while I wonder that did I throw away [the studies] but maybe sometimes I get back to them.

The time after graduation in working life to the moment of the interview

Sofia's work career started already during the studies. Before graduation she started to work as a research assistant at an institute close to TKK. She started there as a summer trainee after the fourth year of study and continued a few years after the graduation. She describes that time as follows:

R: What I really learnt from that time was, of course, the ways [of working] which the academic world uses and does research. But on the other hand, I noticed that it was not my "case" [way of working] – if I had stayed there, I would have become a post-graduate student and then it would have been [being in] that world, or it was not really that world but that way of working and else. Then I

changed into consulting in which I have been now nine [years], it is already nine years ago, and in practice all that time after I have graduated. And there [in consulting] the career path is really quite well-defined, quite similar with everyone. First you are in a team and do something and then you become a team leader and then you become a project manager and so on, it is so, you grow inside the company and that is in a way[how] the career[goes]. But when I think about the earlier work, so everybody brings something with her or him, to the team management, working together and that kind of things… I have completed a rather big change in that phase when I changed [into consulting]. I have claimed that then when I will get bored with this, I do not go elsewhere to do the same kind of job but then it is again a turn. Then it may be that I dig up again the ECE books if I could remember something of those…

I: Yes. So, if I can interpret that the turn of your career path has been the decision to change from the research type of work..?

R: Yes, in a way, because it has clearly been a start for a new type of path for me that I won't be a researcher. I could not return to that path. But occasionally I do think "oh well should I study something just for my own pleasure".

Sofia describes that most of the tasks she performs at work, she has learnt in the workplace. When having worked at a consulting company, she emphasised working and learning in groups and in teams. She emphasises that the skills and competencies needed at her work are not taught in higher education but gradually learnt at work. She describes the learning process as follows:

R: Well, let's say that the things I do at work are not taught at school [in higher education] maybe except that C-programming course. In a way, I did not really know at that time such things [which she learnt at work] existed. So, it has been, in a way, my whole competence has developed during my career, so, in a way, I sell my knowledge and competence forward then the substance of my competence comes along the path that I have gone through.

Sofia would like to stay competent all the time. Her substance field is constantly changing, and learning new technologies is a part of the change. She claims that her tasks have changed more into the project management side, and recently she has learnt the business side of project management. Furthermore, Sofia adds that leadership skills become more and more important in her work. She can see their value to her career; technologies are changing but leadership skills remain and they can take be "taken along" when she possibly changes into different type of tasks in her career.

When thinking about competencies needed in working life, Sofia notes that certain ability for controlling one's life and prioritising is certainly needed. In this relation, she mentions her family, and adds the self-leadership skill [a life management skill] – this skill helps both at work and at home and helps to avoid too much stress. Another important competence needed which she mentioned, was listening in the connection with leadership skills. Yet, she claims that her competence and skill needs are based on her own experiences at work, not on the expectations from her superiors. She reveals her thoughts as follows:

R: But not really, no, I could not say that somebody outside [for instance external factors] should say that I should learn something because everything comes inside, my supervisors have certain expectations. But-- they [her supervisors] go much according what I have said, what expectations I have and where I would like to go [in learning new competencies] ---But I am still in a company in which my expertise is being sold to others. Then, of course, the product has to be like the company sells. Yet, I am [working] in a job in which I sell it myself, so [this topic] has both sides.

Definition of expertise and expert by Sofia

According to Sofia, a difference between an expert and a non-expert is that experts can analyse and structure their knowledge and they are able to tell about it to non-experts. She compares experts to teachers. Expert is almost like a teacher, s/he can analyse the data and bring it to the listener. Furthermore, Sofia defines experts as people giving knowledge from where to find data and from where to find possible solutions, based on their experience.

She defines that at the moment she is an expert of her certain narrow field in which she is working. She added that she could naturally develop her expertise in enlarging her points of view to keep up with the development and be able to compare one's own expertise to that of others. It is also important to increase knowledge in some other field [beside one's own field].

Sofia's expertise development as a path

A typical path of expertise in Sofia's field is to begin working in projects in a team. She described the work as follows: *"do such jobs really by truly rolling up your sleeves, when you can really learn the fundamental questions"*. Next, she started to plan and design projects and to steer others. Through that phase she developed constantly her expertise by deepening and expand-

ing it. Sofia adds that her expertise growth is based on the experience when designing the same type of solutions for various clients. She claimed that her expertise is only her own but at the same time she is also representing solutions on behalf of her company in which she works.

> *R: But that is also expertise that you can bring out that it is not only my expertise, I am not representing myself in it [in the process] but the knowledge of the entire company. In a way, I can represent it so that okay, I have done these [projects] five times, but this has been done at least 250 times already [at our company] and I am able to collect that experience also from the others.*

Sofia summarises that the typical path in her field is doing the task first yourself. Then, by going through other's experiences, she searches their knowledge by asking and working by trial and error. **Figure 12** describes Sofia's career development.

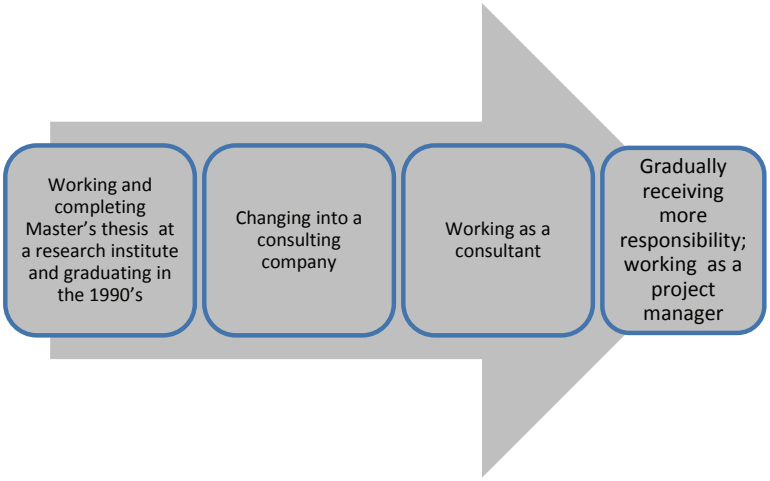


Figure 12. *Sofia's career path (author's original diagram)*

The future and the most important aspects at work

According to Sofia, most important in her expertise development is to keep oneself up-to-date. Second, she would like to acquire new challenges all the time in order to receive more information and expand her current expertise. Sofia justifies her thought with an expression that *"it is not only that I [should think] I am living in that bubble that hey, I do know this"*.

Sofia finds it also important that she enjoys working in her career and that she has to experience that she is proceeding in it. So far, she has experienced

that she is in that stage that she has been able to make progress and develop as an expert. However, she mentioned her family and the balance between various areas of life:

> *R: I enjoy being at work and I do want to work. I know that if I just do something else [than work] so that's not for me, but however, I am a little bit lazy, I do not want to invest too much energy in work [life]. And besides, I do want to keep my family in there, if my family really was disturbed because of my career, then my family would win. That is the way the balance should be. I recently said to somebody that I would probably leave my current work. In some phase I would start to think about that this may not be my "thing". But then it can be like that someday I will get cross and I walk home through the pay office and [then] I start to think what I could do next. Otherwise, despite I am quite considerate, I think in this type of big changes it may be that it [the idea of leaving] will come one morning that it has to be done instantly. I have told as a joke that I will finally become a mathematics teacher somewhere so I could have long [summer] vacations and hopefully a little shorter working days, but I would not teach very young[students], not teenagers, but maybe at upper secondary school, or at polytechnic. But—in a way, I feel that I have an open mind as to what the future brings along. It can take me into many directions.*

From Sofia, I move on to Charles who has had a long career after graduation from TKK. He has worked in several companies, some years abroad and at the time of the interview he worked at Nokia. I named him after *Charles-Augustin de Coulomb* (1736–1806), a French physicist who published the Coulomb's law in 1785.

Charles

Charles graduated in 1988 from TKK with electronic circuit design as his major subject. The laboratory of electric circuit design became a part of the Department of Micro and Nanosciences on January 1, 2008. He has worked in the industry since his graduation, and has acquired approximately 20 years of work experience. After the interviewing period in September 2008, Charles started a two-year-working period abroad in the beginning of January 2009. Regarding the group of respondents in this study, he belongs to the subgroup of those who have started in sales and technical support, and changed gradually towards the middle management leading a team of experts.

The time span before the studies at TKK

Charles recalled that during his school time he had been rather good in mathematics and physics although he said he was not so enthusiastic about technology. He applied to TKK because it seemed to be an easy option for him. He passed entrance examinations well and got accepted and furthermore, found the studies interesting. However, Charles adds that engineering was not his favourite profession. The following quotation describes his thoughts:

I: Would you tell how did you originally get interested in technology and engineering in your childhood?

R: -- I do not really know was I ever that much interested in [engineering] – I maybe somehow drifted into the field. It was sometimes in the upper secondary school, when I matriculated, I started to think what I could do when I grow adult, and then when I always had been good in mathematics and physics and in these [subjects], so it [TKK] seemed to be an easy option [to apply to] 'okay let's try, what if I went to the entrance exams', and I was easily accepted and it was interesting then and I just stayed in there. It [engineering] has never been my favourite profession, but I have never really had one…

I: Yes. But, however, you were interested in mathematics and…

R: Yes, in that sense I am maybe not a traditional engineer that I have never been interested in any gadgets or machines, I do not want to bustle with computers for long…

The time span during the electrical engineering studies at TKK

Charles applied to ECE in the 1980's and had not considered any other choices. He had thought that he was most interested in electrical engineering. He was satisfied that he was accepted to TKK where he wanted to start the studies. When he recalls his studies, he says they were very theoretical, and he has needed the topics and subjects taught very little in working life. However, he reflects on the fact that the courses also needed to be theoretical in order to educate becoming researchers. Furthermore, he recalls that the quality of teaching in the courses was very varying. Some courses were very demanding and arduous with a difficulty to receive the study weeks, and by comparison, other courses were very easy. He mentions academic freedom from a student's point of view when thinking about his study time in the following quotation:

R: But the actual studying, it was really much [free], you could decide very much about your own things during that time, what to do and when to do, if you do not want to do anything so nobody is compelling you to do something, so it [studying] was really free.

Charles completed his engineering studies in 5.5 years which is comparatively a rather short time. He had not set any targets for his study time. He adds that his advantage was that he was working at TKK from his third year of study on. He was teaching as an assistant at courses and exercises and did his studies at the same time. Therefore, he could easily participate in the courses when being and working physically at ECE in Otaniemi.

The time after graduation in working life to the moment of the interview

After having graduated in the end of 1980's, Charles worked one year at ECE as a researcher with the thought of continuing till the doctoral degree. However, he told that his motivation for research-oriented work was insufficient, and decided to search for other work options outside TKK. He describes his thoughts [with laughter] that he had an idea about going to a *"proper work"*. He searched various options and received the idea of going to work abroad. He was probably influenced in international projects when working at TKK. He chose to go to Austria where he worked for five years in electrics design tasks. During his work period in Austria he became very interested in sales tasks and after having returned back to Finland, he worked in sales and technical support. He recalls since that he has gradually changed into a business development-type of work. After, having worked in sales, he changed to Nokia to sourcing tasks.

When considering his work period abroad, Charles felt it a somewhat disappointing experience afterwards. He had expected it to affect more positively his career development. He reflects it was useful for his own development as a person but he does not see any importance with it to his actual career development. When he had worked abroad, he had studied many articles and other literature about the work experience abroad generating positive effects in one's career.

Charles sees that during his career he has not much needed traditional electrical engineering knowledge learnt at TKK. He has been in that type of tasks in the beginning of his career but not much afterwards. He claims that it has been "*good background knowledge*" and continues that studies in electrical

engineering were very theoretical having not much to do with his everyday work.

Charles describes that he has acquired competencies in technical knowledge although which he claims he has gradually started to forget. Then he adds a competence of business understanding which has grown more significant for him. Furthermore, he adds legal matters and law, and leadership skills as important competencies in his work career. He describes his competence development with the following quotation:

R: Oh well, it has been quite clear when I think about the study time and then I when changed into work life, so there in the studies I got a certain type of technical competence and engineering knowledge which I used in the beginning and it got developed [in him]. But then when my jobs changed more and more, to a little different type of work, then I got [more] these, business knowledge and commercial competencies, knowledge of finance world and then [from that on], this has increased an, on the other hand, when I have worked longer and in a way my responsibilities have grown, so then I have had to create these, these kind of soft values, for instance, leadership skills and knowledge of finance world, legal matters and these, well, it has changed all the time…

When Charles reflects his future career and competence development, he sees as most urgent needs to develop his skills in management and leadership, for instance, in order to be able to lead teams and teamwork. When considering his career, he can perceive enormous changes in the surrounding world during the last 10–15 years, which have driven functions of companies to certain directions. He states that if he desires to work for his employer, he has to act according to those changes. Charles describes this with the following excerpt:

R: This environment has changed incredibly lot, let's say during the last 10–15 years, it drives operations to certain directions and each company specialises its functions somehow. And if you want to work in there [at the company], so then you have to act according to that. So, if the field, in which you have worked before, is not any more important, so then you have to focus on something else. So, this is a thing which has affected at least my work. So rather if the company's operations model has changed, so rather then, if you have not for any reasons wanted to change to other kind of work, so then you have stayed in the company and changed your own work [field] than look for such people who want to change work [in order you can keep the old job]. Yes, the environment [has an effect], of course, those people with whom you work, and there are many people, so you have to check that the group [team] has knowledge from all fields. Then if some field there is not [knowledge], then you have to check 'okay, somebody has to

learn that'. I have also done like that, that 'okay let's learn about those things a little so I can take care of it in this project'.

Charles mentions globalisation as a factor which has changed his work and working environments to a great extent. He describes the situation when industry has moved its units to the other parts of the world and employees are expected to follow the work when possible. People working in Finland concentrate on the different type of tasks, or co-ordinate and adapt their environment according to the change. He also wonders whether his job will remain due to the change:

R: It is really so that the work what I am doing right now could be performed anywhere [in the world], it is not related to a certain place. I don't feel there would be a threat losing my work because it is quite the same where you perform it when you act in a global environment like this. But surely it will be that kind of work it will be performed all over [the world]. This [Espoo] belongs to one of those places.

Definition of expertise and expert by Charles

According to Charles, expertise is to be able to dig up the facts from a certain field and to know what is relevant in it. Expert can bring the facts *"to the meeting table"* in order to support decision-making. He thinks that expertise is created only through experience, by doing tasks. It is possible to learn basic level of expertise through studies and books, but real expertise comes through experience, and it cannot be learnt any way else than working and performing tasks at work.

The development of Charles' expertise as a path

Charles thinks that in certain fields he has reached high level of expertise in his career. In some other fields he has changed into other, more general level in his tasks; into more business and administrational type of tasks. Furthermore, he has acquired needs to develop his skills and expertise in those new fields and learn new knowledge. Charles estimates that his expertise is approximately in the middle phase, and he would like to expand it "*sideward*", into a horizontal direction. He regards it important to constantly learn new areas of knowledge because the environment changes. The following excerpt describes his thoughts:

R: -- You have to always learn new things because the environment is changing all the time. At least you learn to understand to which direction it is changing, and then you can use your own experiences and take them to the right direction, and you are not stuck there, in your "box", in that box where you have always been because it may happen that tomorrow that box is not needed anymore--- That you are able to move on, or steer it [one's expertise] to that right direction and that can take place through studies, through further training, to search for those new directions.

Charles supposes that in the very beginning of his career he was working with overall tasks in the field, and somewhat later on received his own, small projects. He describes that at that time *"he wanted his own little box in which he can tinker something"*. In his current job, after 20 years of work experience, he claims he would not stand anything like that at all. Now, he requires something through which he can expand his views. He considers this to be the largest change in his thinking – he is more open to take responsibility over larger size of units and projects. His career path is described in Figure 13.

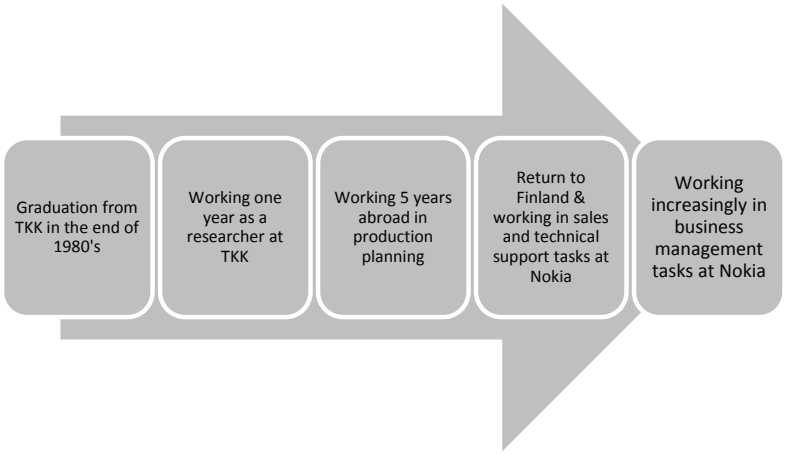


Figure 13. *Charles's career path (author's original diagram)*

The future and the most important aspects at work

Charles finds that one of most important aspects in his work or career is variation. He claims that he may be not able to work with same tasks for very long, at least very intensively. He says that another important thing is to feel to have accomplished something, to see results of one's work. He would not like to become a high-level manager in a large company in the future, but to

develop more horizontal expertise in his career. Charles claims that it is sufficient for him to see tasks from a wider perspective and from a different viewpoint, which affects keeping his motivation and interest up. He says that *"when work is varying—it is fun, and [another thing that] [when] you do not know what the [next] day brings along, that is fun"*.

From Charles, I move on Erwin who has worked in the telecommunications field during his career. He belongs to the 'manager' type. After graduation he has not worked much with the substance he studied at TKK but he has moved to another direction, and has been working as a manager for some time. However, he leads a unit of experts in the telecommunications field. In this study, he was named after *Erwin Schrödinger* (1887–1961), originally an Austrian physicist, who is renowned for the Schrödinger equation in wave mechanics.

Erwin

Erwin graduated in 1992 from TKK with telecommunications engineering as his major subject. He has worked in the industry since that, mostly in various managerial tasks in Nokia. After the graduation, he has acquired about 16 years of work experience.

The time span before the studies at TKK

Erwin recalls that at school he was good in mathematics and physics. He tells that his both parents were biology teachers and he claims having had no engineer role models at home. Furthermore, he tells that he did not have any perceptions of engineer's profession.

He had a good friend at his school time, whose father was an engineer, and the father asked his son to build electronics at home. Erwin got also very interested in electronics as well when he followed his friend's hobbies. He recalls that as a teenager in the secondary school, he started to build very much electronics in his free time. Later on, Erwin and his friend both applied to TKK and started their studies together. Erwin had received an idea that TKK was *"an easy choice"* – entrance examinations to TKK were easy and no extra reading was needed as compared, for instance, to former Helsinki School of Economics HSE (currently Aalto University School of Business).

When applying and choosing between the departments, he had also considered chemistry due the concreteness of the substance. He recalls that many of his school mates applied to the Department of Industrial Management. He thought he would not have liked to apply there because according to him, people wanted to study there mostly because of the status, or the image of the degree programme. Furthermore, he adds that he was not interested in basic industry but in electricity. He recalls that in the upper secondary school he liked most electricity in physics, for instance, DC circuits. He describes his choice to apply to ECE as follows:

R: I thought this is certainly the thing; I am not so enthusiastic in mathematics that it would be my 'thing'. And about telecommunications, I was naively thinking telecommunications to be the future field, and I was right in that. And I ended up here [at ECE]. Many of my school friends applied and were accepted to the Department of Industrial Management but I had the opinion that I don't want to study there because of the status. Then, at the same time [instead of industrial management] you could have applied to the Helsinki School of Economics. As a second alternative, I probably had the chemistry department and that [subject] was somehow concrete to which I could compare my school experiences. And, well, for some reason, it was electrical engineering. I was not interested in basic industry, it possibly started from there. I liked these electricity things at school, and DC circuits were the nicest things in physics, so it came from there.

The time span during the electrical engineering studies at TKK

When recalling studies and the study time at TKK, Erwin says he hated studies and studying at that time. He had always been a good and motivated student in the upper secondary school. So, the feeling being not a good student at TKK was new to him. He says that the basic studies at ECE were very hard for him, and he had difficulties in being motivated in the studies. He tells that for him studying mathematics was like squeezing the blood out of a stone. At ECE he noticed that he was not among the best students, especially in mathematics and this made him to change his viewpoint. He understood that this was a place for growth for him. He said that he started to grow in that way that he started to ask himself what was the benefit of the studies for him. Later on, when he continued to Master's level studies, he started to like them more, especially when having chosen telecommunications as his major and industrial management as minor subject. However, he recalls that the first two years of study according the model schedule, were very hard with mathematics, physics and the other courses in the beginning. He describes his thoughts as follows:

R: It was, honestly saying, I hated studying. I had been good at school and the basic studies at Otaniemi were very strenuous for me. Getting motivation was hard for me and, of course, it was a place for growth for me, because I was used in being good [student] and I had always been motivated [in studying], then suddenly I noticed that I am not motivated, and that was a mysterious feeling for me. That is, mathematics was like squeezing the blood out of a stone, at least at ECE that time. I don't know how it is today. At that time, you had to study A-mathematics, and it was very hard to get motivated into it [the subject]. I still remember having received 16/24 [points] in the first mid-term exam, and I thought it was a very bad result, and that remained the best performance in my mathematics history.

In a way, I had experienced that kind of growth that I tried to find out what kind of benefit I could have of the studies, and I did not feel that I could ever use any Schrödinger wave equation at my work. But then I got further. I was reading telecommunications as my major subject and then I had industrial management as my second subject, and they were interesting. Then it [the studying] started to have connection to something. But I think it was very hard [to study] at ECE at that time. If you followed the study guide, so the first two years went into the basic studies as mathematics, physics and then to that electricity set if you had a share [of courses] at each laboratory.

When finishing his studies, Erwin had realised that there were different types of becoming engineering graduates: those who were "born as engineers", who had a major subject in telecommunications or in electronics. He realised during the studies that he did not belong to this group – he did not have a deep passion in circuit analysis or computer science. Due to this he chose his second major subject outside ECE. He describes his thoughts in the next quotation:

R: When I was looking at the peer group there I saw there was a lot of people who were born engineers, either in telecommunications or then in electronics. And I realised I am not like that, I was not born an engineer, my passion, let's say, into circuit analysis or computer science, was not so deep, so I thought I need to be a realist, I won't be motivated in that and that's why I took the second major outside [ECE] ---

I: I would like to ask how you would describe this expression which you used "born an engineer". It was so interesting expression, how would you more broadly describe what it means to you?

R: Oh well, to me it meant to have a right passion to go deep into that subject. I found it fun to learn how a transistor works but the point that I would have spent evenings to think about them, building something up or I could have been sitting an evening after evening at the computer centre coding something, so I have never sunk so deep - when there were people for whom it was a work, hobby, and

passion at the same time. And you learnt really fast to recognise to whom it was that, and to whom it was not. Then I realised that, okay, there are people in the world for which this is much more than learning things by the book. And for me it was much more a means of finding a nice job than a profound passion into that [to electricity].

When reflecting his studies and the studying at TKK, he regards learning of communication and personal relations skills very important. However, he claims that in his study time, there were not enough possibilities to study them. He would not have preferred separate courses in communication, but integrated into other studies. He recalls that at his time, there were voluntary oral communication courses which took place only at inconvenient times in the evenings. Furthermore, he adds that there should have been much more emphasis on language studies. He makes a comparison between his friends having studied at HSE (former Helsinki School of Economics) that *"they were from different worlds, and in Otaniemi people [teachers] are satisfied if students have been lured to take any other languages after the mandatory basic Swedish course, when at HSE the standards [concerning language courses] are really high"*.

Erwin reflects his studies that the subjects taught at ECE were both scientific and non-scientific (more applied). He sees that it depended much of each professor in which way they could integrate scientific thinking into a course. Professor's own passion or enthusiasm could well be seen in the teaching.

R: —and the passion to the subject and the way how the professor handled it [the subject], it is so contagious. But if you saw that the professor was just a kind of 'bread priest', it was depressing.—I have sometimes said that the reason why there are so many good telecommunications engineers in Finland in average is because the teaching was so substandard that you had to learn to work independently—it was incredibly confusing that you are at the best technical university in Finland, and you have to study something like that. In the beginning of the studies there were such teachers or professors who could attract your ability into scientific thinking but later [in course order] you studied, worse it became, and it just went vice versa [courses consisted of less scientific thinking].

He completed his Master's thesis in telecommunications field. He recalls that the topic of his thesis was supposed to be quite application-based and it turned out to be very theoretical instead. He revealed that when writing and completing the thesis, he could realise limits of his own abilities, and later on in working life he found his way more into the marketing field. To him, the phase of completing Master's thesis was a good opportunity to seek one's own

limitations and directions. In the following quotation he describes his perceptions:

R: My diploma thesis which I completed then, it was very, it was supposed to be very application-based, and it was extremely theoretical, and then finally that solved the fact that I understood where the limits of my abilities were and later on I have found my way more into marketing. But here in technology I want to stay. It just got revealed through my studies what kind of abilities I have. And whether I am a person who plugs away in a lonely chamber, or whether I want more to be involved with people, and I came into the conclusion that it was the latter option.--- As a consequence of my thesis, I got drifted into a kind of research work at Nokia, and then through the work I could quickly find out that I am not a researcher type of person, and I started to look for other jobs in the same context which was telecommunications and mobile field where I could work more with people.

When thinking about the connection between his studies and work career, he sees a straight connection that he has sought work in a technology-oriented company. He sees as a self-evident benefit for his career that he did study five years in Otaniemi at TKK. There he received a general scientific-oriented foundation, pondered repeatedly and daily, more or less depending on the circumstances, electrical engineering.

The time after graduation in working life to the moment of the interview

After graduation in the beginning of 1990's, Erwin started working at Nokia. He tells that he had his first turning point in the beginning of his career: he realised after having worked for some time in research tasks that he would not make a researcher. He recalls it to be a very good decision for his career because he claims that *"person has to do things one most enjoys because then you are at your best and the final results are best possible for all"*. He recalls his own time and studies in Otaniemi and claims that engineering studies transformed his views about his own abilities, set another perspective or lens through which he saw himself in an engineering context. He said that it affected him both in good and poor ways. He describes his thoughts as follows:

R: Otaniemi, in a certain way, let's say, put my skills and abilities through another perspective, in good and in bad. In a good way, that I became a realist, in a bad way that I became overly realist.

He recalls that the second turning point of his career was that he could admit he still had a lot of ambitions. He says that he was able to admit *"it was quite ok"* to be ambitious. Due to his own remark of his thoughts, he claimed that he does not have a certain type of "wrong" kindness, or compliance any more. Therefore, he has demanded or taken certain tasks in his career which he *"is worth of"*. He can trace these feelings of being "*too kind"* or too modest to some periods in TKK studies when he thought of being a mediocre student, not even that. Furthermore, he claims that he has got rid of excessive kindness in working life. He noticed that besides his theoretical abilities and skills, he has learnt other competencies. He has used them in order to gain himself the type of position in working life that he *"is worth of"*.

He regards analytical thinking as one of the main competencies he has needed at work. He believes he has learnt more of it during the first years of study with mathematics and other scientific basic subjects at TKK. During his work career when having met people from other educational backgrounds, he has noticed the difference in their way of thinking and has thought it has to do with the education. Another important competence he mentions is responsibility and independence. He describes that to him taking responsibility is an important competence needed in working life and adds that *"alarmingly few people seem to be intrinsically taking responsibility"*. He continues that this competence cannot be learnt at school, but through working and taking more responsible tasks. However, he enhances that the seeds of responsibility can be sowed during the studies, for instance, with various requirements of the courses, and after the studies *"you notice then that it was worthwhile that professors were grumbling [about your studies]"*.

Furthermore, Erwin adds that interpersonal, group working, and communication skills are also important competencies for him. He thinks that he could not have imagined their importance when graduating from TKK, but he has needed them throughout his career. When thinking about competencies needed at work, he mentions that *"we are living in a web economy"* which has effects both on people's work career and employers. He claims that companies functioning in Finland are not any more Finnish-owned but international and adds that Finnish engineers cannot be *"little mousies"* any longer but create good skills in international sales and marketing.

In brief, he describes his career till today so that he has gradually at intervals received better tasks. He claims that he has not deliberately sought for them only by making proper moves, but he has been seeking for something which is interesting and concerning the substance of his work. He has had

marketing and management tasks and through those he has *"reached far better tasks he could have ever imagined"* and *"through naïvety"* he has reached a very good position.

Definition of expertise and expert by Erwin

Erwin initiates his perception of the definition by mentioning first expert organisations and their existence. He claims that an expert is a person with abilities to help others, or the organisation independently in some questions or projects. According to him, an expert has to posses a *"certain theoretical and experience-based load [knowledge]"* to carry with.

According to him, an expert goes rather deep into the chosen field, and from the beginning of the career to choose a rather narrow scope. Expertise goes deeper and wider up to a certain point in which s/he chooses, or the decision is made by others whether to continue in *"the expert path",* or to take another path more into the direction of general management tasks.

Erwin's expertise development as a path

Erwin reflects that his career path (see Figure 14) and recalls that in the beginning he has followed the expertise path. In the end of 1990's he was in the crossroads of choosing his direction. He took his way into general management path, and claims that he cannot say to be an expert in a deep knowledge level any more.

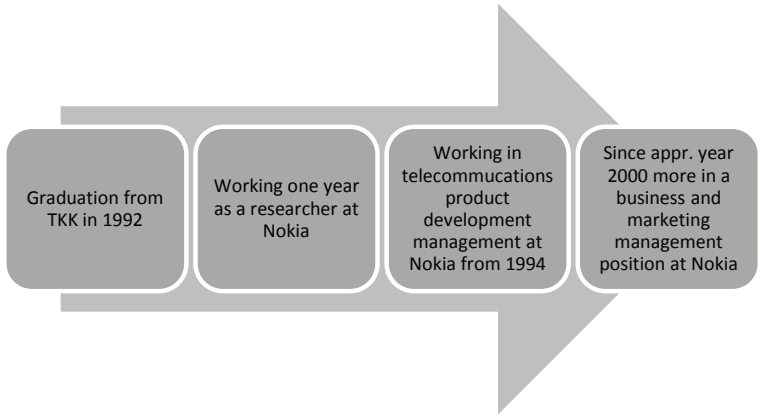


Figure 14. *Erwin's career as a figure (author's original diagram)*

The future and the most important aspects at work

Erwin claims that he is very satisfied with his career in general. He says he has acquired a very good job with an interesting substance. When thinking about what his expectations in his twenties were, he claims he has received much more than he believed then. Moreover, he has proceeded even further in his career. He describes his thoughts:

R: I am very satisfied at this moment. In a way, I believe I have a good job in which the substance is what I like and enjoy. And when thinking about the status [of the work, I have reached much more than I expected when being around twenty. And I am awfully satisfied that it has happened without having to do any compromises on the things which I believe are my 'things'. In a way, there I can see my naïve belief that by doing those things which I like and which I enjoy, then all's well, that ends well.

Erwin reflects that one of the most important aspects in his career path is colleagues and other people in general. He adds that it is also very important for him not to work by oneself *"in a lonely researcher chamber"*. He finds it also very important to receive feedback from others. He reflects that in Finnish culture, supervisors seldom give enough feedback to an employee which is not a positive thing. Therefore, he claims that during his work career he has also enjoyed such work tasks which were assessed with "cruel and plain numbers" and in those tasks he has noticed that he receives clearly either good or bad feedback which is *"rather objective"* to him. He emphasises that he has enjoyed his career in especially in technology marketing and management, and uses an example describing this he would have *"never gone into bond marketing"*.

He finds some weaknesses in viewpoints when having received engineering education. He recalls that the students studying in Otaniemi were rather homogeneous, and formed a kind of restricted social circles, or spheres. He described a typical restricted *"engineering path"* as follows:

R: If you think about the world of a typical engineer; in upper secondary school large courses in mathematics, in average all boys, who have the same way of thinking. Then you go into the military service, in my time there were no women at all, nowadays just a few now. Then you begin at ECE with about two hundred and fifty students of which maybe ten are women. Then finally you end up working at Nokia, well, and then your world view is rather restricted. So, extension of it would be very good for your mental health, but also for your work and

career. So, it's not easy to work with an Italian-Argentine manufacturer designer with that kind of background.

Erwin finds curiosity a good source of learning in his career. He adds that it has been *"a privilege to get acquainted with people, for instance, from music industry, or from industrial design, which are totally mystic areas for a basic engineer"*. Furthermore, he adds that his work has been very people-centred and networked-based which has been a good thing in his career. He compresses his career in a philosophical statement as follows: *"It has been like that – philosophically I believe that a person has to do things which s/he prefers and is awarded for that, and happily it has been like that with my employer."*

From Erwin, I will proceed to Lisa, the second female respondent in this group. Electrical engineering was not primarily her first choice, but she applied first to the Architectural department at TKK. However, she was accepted to electrical engineering and began her studies there. She led active student life in a student hobby group, graduated and entered working life in 1996. She has been content with her career and states that it has been "a *sum of happy coincidences"*. She was given her pseudo name in the story according *Lisa Randall* (1962–) who has been the first female tenured professor at theoretical physics at MIT and Harvard University.

Lisa

Lisa graduated in 1996 from TKK with Electromechanics as her major subject. Excluding some periods of maternity leave, she has worked in the industry.

The time span before the studies at TKK

Lisa believes her career choices originate from her childhood. Her father was an architect and she recalls her father being rather multi-skilled in household tasks as well as her mother. In her family she learnt a way of doing 'things' by hand. After the upper secondary school, where Lisa had been rather good in mathematics, she applied to the Architectural department at TKK as her first alternative. She expressed her thoughts as follows: *"I was rather good in drawing, but my sketches were not good enough for them"*. As the second alternative, she applied to the Department of Electrical and

Communications Engineering, and got easily accepted there. She recalls having chosen this department because of "*largest scale of all the possibilities to study*" but she mentions having no *"passion"* to the subjects in the electrical engineering curriculum. Lisa continues that when she considered other departments she thought that *"machine and mining and mineral departments to be too easy"*. She did not consider industrial management or physics either because she thought *"at that time the Department of Industrial Management was the most difficult one to get in, and physics next to that and besides, physics was too difficult a subject."* She recalls having thought that electrical engineering studies to be *"the golden mean"*. Lisa describes her thoughts as follows:

> *R: I did not have any major ambitions towards technology, but there was the fact that I knew I am awfully poor in reading and I am rather good in calculating. I would not have been able to study law or something like geography, or biology at University of Helsinki, not even to mention medical studies. This [engineering] was a kind of a compromise.*

The time span during the electrical engineering studies at TKK

When reflecting her study time, Lisa recalls that she did not set any ambitious targets for her studies. In the beginning of her engineering studies, she went into the music activities in her free time which gradually started to form her way of life. She created a large network of friends in the musical group, and her network still was there at the time of the interview. Furthermore, the activity took much of Lisa's time which had an effect on her studies.

Lisa remembers that when she was at a preparatory course for TKK, they had a teacher from ECE who informed the participants: *"Even if you were the best ones in your class and in your school, so there in Otaniemi there is always somebody who is better than you"*. She says she found it to be quite true and adds that *"I also was the best of my class in the secondary school, in the upper secondary school not quite, but far from the best in Otaniemi [at ECE]"*.

She participated in the mandatory lectures and completed the required exercises, but as most of the lectures were not mandatory, she gradually started to complete the courses only by taking the final exams. During the first years of study she recalls having received many "ones" for course grades [scale being from 1 (poorest) to 5 (best)]. She admitted that her way of studying at TKK was "*rather unambitious*". She saw a huge difference between the stud-

ies in the upper secondary school and at TKK. She reveals her thoughts as follows:

> *R: It was different because it was so difficult. I did not understand it [the substance in general]. At school, all the things were easy and you managed there almost without doing any homework if you had a good memory and so. But there [at TKK] even though when sometimes you tried to work hard, you still did not understand. Well, I don't know if I had understood more if I had attended all the lectures. But it was that when you learn to calculate something [equations], then you don't really understand how it is connected to the larger unity, and what kind of connection it has to electricity that I could calculate some Laplace Transform, right now in this certain point. So what do I do with this information? That was, you know, science, and it was difficult, [it was] a science university.*

Lisa found the studies very theoretical and not so motivating, especially during the first years of studies. Later on, when studying more advanced courses in her major subject, she found them more interesting and consequently, received also better grades. She did not find teaching good enough in the mass courses. She described the teaching as follows:

> *R: Well, it was rather theoretical, there were some lecturers who just talked and flung slides on. Those subjects were so theoretical although I don't know how they could be turned into more interesting. Well, it was like that the professor talks in the front [of the lecture theatre] and students copy [the substance] from the slides and understand it if they can. Maybe five per cent [of the students] understand it and the rest copy the things down to their own books. At least at the mass lectures it was like that. But the further you studied and smaller the groups in courses were, so of course it became more personal and there was more a kind of personal touch in them [in courses] somehow.*

Lisa revealed that the graduation from TKK has been very important for her. She regards the Master's degree somewhat a status thing for her. She had some difficulties in her personal life when completing her Master's thesis, for instance, the decease of her close relative, which affected much that time period in her life. However, she claims that she is satisfied that she has studied at TKK – *"it has absolutely been the best place for me, and I have never afterwards thought that I should have studied to be a medical doctor, or should have done this, or should have done that"*. Furthermore, she is very content with having *"gone through the tube and got out of it [her graduation from TKK] despite all of the difficulties and motivational crises—it is a huge thing"*.

When reflecting on her perceptions of career development, she thinks when she studied there were two types of girls at ECE; those who were a sort of "*fast track thinkers*" and those who were a sort of overly realistic students. She admits of belonging to the latter group. She thought they were overly honest to themselves, blaring out *that "we understand nothing here [at ECE] and we cannot do these things [studies] and 'this is of no use ever' and that we blared out maybe too much".* She ponders that the others, in particular boys thought that *"you have to go through the tube and become a Master of Science in Engineering according to your family's and other relatives' expectations and then become a high-level managing director".* Lisa thinks that for female students it was easier to accept the reality of one's own skills and limits, especially in engineering studies.

The time after graduation in working life to the moment of the interview

Lisa claims that her work career has been *"a sum of happy coincidences".* She received her first job already during the studies at an office-type of electrical engineer unit and via various personal links and connections she has moved on to other companies. She has been working with transmission systems at a transmission grid company. She completed her Master's thesis for this company and worked there for some years after her graduation. Currently she works in production planning tasks at an international listed engineering solutions company in the Finnish capital region.

When asking about the turning points in her work career, Lisa thinks about the question and considers her turning points having been more in the side of her personal life from where they have affected respectively her work career. She mentions anew the decease of her close relative which took place at the same time when she was completing her Master's thesis. It caused some delay for her graduation along with a too quick a decision in her personal life. Later on, when changing to another employer, Lisa met her current husband. She describes these phases in her life as follows:

R: So, these personal things have affected quite much my work career, in a way, I cannot actually see these things through my work career. This has been a kind of life path, this thing. I have never been very ambitious about my work career, I want to do a job which I like and which is fun. I do not have any high hopes to become a managing director or climb up to the next level, I find it important that I enjoy being at work.

Lisa can find a connection between her engineering studies and her work. However, she has not used much of the substance and knowledge taught at TKK. She says that she *"never used any differential equations at my work, or any of the mathematics learnt there at TKK, that was so theoretical and this [her work] is something else"*. She continues that in working life she has learnt concrete knowledge of her field, and nobody ever at TKK showed how facts [in electrical engineering] looked like. She also adds that because of the concrete character of the substance, she studied power electronics instead of radio science, for instance, *"in [power electronics] at least you know how the mains cable looks like, that it would be something easier to piece together"*. As an example, she describes that in terrain at work she learnt, how 400kV and 110kV cables looked like and differed from each other.

Nevertheless, she mentions that a type of problem-solving skill, or a way or an ability to solve problems, has been transferred from TKK studies into her work. In this point, she doubts a little bit that she may also have learnt this skill earlier or it could be a part of her basic character. Lisa describes this ability as being able to see aspects from another point of view, or being able to ask whether tasks can be performed differently. She also describes this as an interest to solve problems. She depicts her thoughts as follows:

> *R: So, currently, what I do over there, if I have to compare things with each other, some tables or texts or something, so I rather spend two days thinking how I could automatise this thing, rather than completing it manually during those two days. Well, it is, then, when you have invented it once, then it is of use, and it quickens your work in the future.*

According to Lisa, she has learnt a kind of technique in coping with learning facts which can be used in working life. When the studies at TKK were theoretical and abstract, she said she needed to develop herself a technique of coping with knowledge. She describes this as follows: *"But it is like that, rather much, that you make use of all the possible ways to overcome things. I probably became quite good in studying techniques and coping with things."* When there were only few girls studying, it could also mean that she asked for boys' help when she should perform some more difficult calculations. She admits that girls could use their gender [due to the limited number of women studying at ECE] as an advantage in their studies.

When considering her competencies, Lisa tells that her focus area is the knowledge on databases. She has learnt more of programming and coding, and she continues that this is the area she would like to work most with. She

recalls that the most important skills she learnt when completing her Master's thesis, were information technology skills (Word, Excel, and UNIX). Furthermore, she mentions general abilities such as determination and responsibility, and also an ability to perceive or outline larger unities. She thinks about the future and says she would like to learn more about programming. However, she wonders that the older she becomes, the more difficult it is to learn new knowledge and facts. When considering her current work, she does not have any client contacts but she is mostly working in internal production planning which affects her tasks and competencies required in them. Lisa tells that the company, in which she is working, has a very good community spirit and she adds that the company is rather small which, to some extent, has an effect on the atmosphere at work. After having recently returned to work from a maternity leave, she continues that *"this company as a whole is rather small so all are mates with each other. When this is not any Nokia, here in the whole company there is a very good community spirit. And that's why I could not imagine any other place where I would work. The thought of starting to adapt to some [other] community from the very beginning - that seems to be the most impossible idea for me."*

In sum, she concludes that she has not much thought about her competence development when she does not ambitiously plan her career, but conversely takes one day at a time.

Definition of expertise and expert by Lisa

According to Lisa, an expert knows about everything and much about various sub-fields. She considers her own company as an example and says that an expert cannot be an external person but must work in the company. She uses a colleague of her as a good example; this person has begun as a programming coder and developed his expertise by being able to regard the substance from various viewpoints. To her, experts distinguish much about substance, and how it is used. Furthermore, their tasks include marketing, or experts ask clients the correct questions what they would like to have added to a certain substance area.

In Lisa's field, it is a prerequisite that experts have some academic background in electric power engineering which in particular consists of knowledge about low voltage and high voltage nets.

The development of Lisa's expertise as a path

Lisa considers herself to be in the beginning of her expertise path (see Figure 15). When I interviewed her in autumn 2008, she had begun in a new job after having stayed at home for a few years with children. However, she could be claimed to be an expert in her former field inside the same company in which she is still working. In her previous tasks she worked for five years. She has used a user interface design tool with its applications.

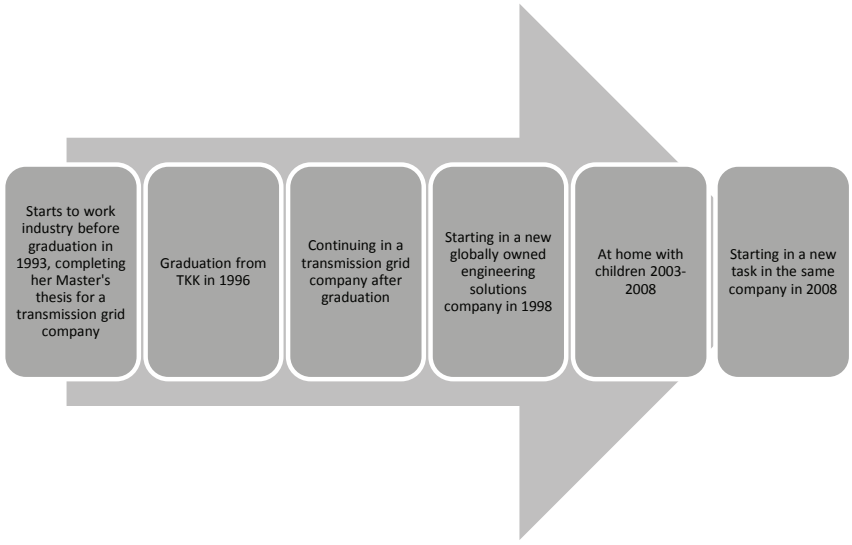


Figure 15. *Lisa's career as a figure (author's original diagram)*

The future and most important aspects at work

As Lisa claimed earlier, she has not much planned her future career. She finds it most important to perform work which she prefers. She notes that earlier when she had less *"adverse factors in the environment such as family and personal relations",* she could concentrate much better on her work tasks. At present, she finds it even more important to be able to concentrate on work on the shorter effective time she has for it now. She emphasises that she does not consider salary level as an important aspect, but prioritises the possibility to enjoy one's work.

When I asked her thoughts about the future, she mentioned family and its members as a value. She finds it important that she and her husband give a good role model to their children in a way that *"parents go to work and it's a*

good thing to go to work". She finds her own situation of having work and family life outside the work at the same time giving balance to her life.

From Lisa the stories move on to Gustav. When choosing a pseudo name for the next respondent, I named him according *Gustav Kirchhoff* (1824–1887) whose theories on electric circuits are a part of fundamental studies in electrical engineering.

Gustav

Gustav graduated in 1994 from the Department of Electrical and Communications Engineering. He has worked 14 years in industry including some periods in Scandinavia and in the Baltic area, and he has become a top-class expert in his field.

The time span before the studies at TKK

Gustav believes that he did not make any exact decisions about his future studies in the upper secondary school. He recalls that he applied to the University of Helsinki to study chemistry as his first alternative. Furthermore, his second alternative was TKK and its two departments; the department of Electrical and Communications Engineering, and the department of Chemistry. Gustav believes it was partly a coincidence to start studies in electrical engineering: he had put it as the first choice in his application papers. He says that at school he was always interested in mathematics. Gustav claims that he has never been a type of *"builder"* or a *"constructor"* but rather a theorist. However, he says that he has always worked with rather concrete facts.

The time span during the electrical engineering studies at TKK

When having started his studies at TKK, Gustav noticed quite soon the difference in studies between TKK and upper secondary school. He observed before long the existence of academic freedom; nobody looked after you and your doings at university – *"--then in upper secondary school there were, of course, people who were looking after you [your studies] and[then] at university, in practice there is nobody to look after you, if you do not want to do anything yourself"*.

He remembers that his threshold in learning mathematics at TKK became much higher than in the upper secondary school although he had been good

in mathematics. He recalls that at his time of study, electrical engineering students completed A-courses in mathematics in which the starting level was higher than the level up to which students reached in the upper secondary school. According to Gustav, *"the first autumn term, it was a little bit like that [difficult], I had a kind of feelings that I wondered how this would go but then when I had noticed that everybody else was in the same situation [laughing] then my feelings got balanced."*

One practical difference in university studies was common usage of English language. All the study books were in English which caused some extra work for Gustav. Although he had learnt English well enough in the upper secondary school, he found it difficult to read and study the course books written in English.

In the beginning of his studies, Gustav was interested in computer science, electronics, and digital technology. However, after the first years of study his areas of interests started to change and he found basic fields in electrical engineering more interesting. He states that it was partly because of large share of mathematics in it. Gustav does not recall any special factors which may have affected his choices but he recalls having subconsciously thought that *"maybe I am not a kind of so called nerd that I would be able to code from morning till night. It may be that it was there in the background but I did not become aware of that [feeling]."*

In the end of his studies at ECE, Gustav received an opportunity to study abroad at a European university. In that phase he had completed almost all the courses and he should have started working on with the Master's thesis. He got very interested in the offered scholarship because he *"knew that some major "names" in the field of his special area worked in the same [foreign] University and that's why I got interested in [going there]"*. Gustav mentions this decision to be a type of decisive turning point in his career, as he expresses it:

> *R: "There [studying abroad] I learnt English properly. Then I also learnt about other topics as well. I had not been very extrovert [person] earlier so this opened up my world quite much besides the teaching there [abroad] was really excellent."*

He recalls when studying as an exchange student, he had a sort of special status. The local university offered also fee-paying degrees for students outside Europe, and Gustav could attend lectures designed to those students almost as a sole participant. He adds that the education he received there was

excellent. He studied nearly one year as an exchange student, and right after returning to Finland, he started to work with his Master's thesis. The last year of studies before graduating, he already had a work place in the industry and completed his thesis there.

The time after graduation in working life to the moment of the interview

When applying for his first work place in the beginning of 1994, Gustav recalls that probably the worst recession phase was going on at that time in Finland. However, he received the first work place he had applied, and started to work as a designer. He worked in this job for nearly four years but started to require some change in his work tasks.

He changed till another employer in 1997, still working in the Finnish capital region. His new work tasks were in the power plant field. He was working as a designer but also started to have tasks in sales area. He remembers that he had quite much to study in the beginning – on project management, for instance, how to write offers, or subcontracts. He recalls this phase as follows:

R: I had to start from the beginning with power plant things, and I had quite much to study there when I started and I had to do offers and kind of larger projects, then I had to take care of the projects and to do all subcontracts, and then to take care of after-sales tasks. So it was a kind of job then when I started there that all the folders were put to my desk and I was told that "take a look of those" [laughing]"

I: How did you feel, how was it like, [was it] hard?

R: Well, of course it was but I had got some basis [domain knowledge] I think the things started to clear up probably quite well. I started to work with things, I studied them what's this about and how I should do these and what kind of machines these are. Then I thought about it. I did those offers and thought about the whole concept how I should do it and what the competitive factors were. So, I started to get sales little by little and things started to expand. There in the beginning, we received sales only every now and then, and it was partly because this field [of business] was new in the company. These sales and offers had not been done much for external clients.

Gustav believes that he was working and creating a new field in a way as a pioneer in this job. In the next phase, he recalls that the company started selling projects and machines in Sweden and he was working much periodically

there in order to complete various surveys and analysis on the market conditions for his employer. According to him, Swedish clients and partners were very technically oriented. For instance, there were many Doctors in technology working in the companies. Furthermore, he described that working with them very was very much individual, consulting-type of work. He had much work to do with several surveys because he claimed that he *"would not have managed at all with them [Swedish clients]"* without theoretical background work, such as reports and surveys. He adds that he was even searching various, old research report series at TKK libraries in order to find further supportive information.

He began to progress in his career. Later on, he was working as a project engineer and as a project manager. He describes that his work was very independent covering the whole lifespan of energy projects. The company in which he was working had several organisational changes and its functions and businesses expanded rather much during that time. Then, the company gradually started to focus its business so that the unit in which Gustav had been working was sold to the other companies, and only a minor part of the earlier business functions were left.

Gustav considers having two significant turning points in his work career. The first one was when he received his first work job after his graduation. In that position as a designer he learnt the foundation for his work and, acquired expertise. The second turning point took place when he changed to the next company where his work tasks altered rather much. When reflecting on the connection between studies at TKK and his work career, he considers the TKK studies as a good foundation or basis in engineering and the rest [of the knowledge] to be found out by oneself. He describes his reflections as follows:

I: How do you see the connection between your studies and your work career when having graduated from ECE? And when you have been working for the last 14–15 years?

R: They do have a certain connection. I do remember that already during the studies there was that eternal complaint and whining about the degree because it does not educate you directly to work and something like that. I myself thought that thing more so that the principle was that you receive basic knowledge, you receive the foundation but then you have to learn the practical side by yourself.

When reflecting on the substance of the studies, he sees that the borders between different departments were too strict at the time he was studying at TKK. He mentions when having studied at a specific laboratory, it would have

been a good combination to study a certain number of courses in other engineering areas. He claims that when starting in his first job after the graduation, he had to learn mechanical engineering in practice. The field of has been very significant in his career and he has mostly learnt at work. He describes his thoughts as follows:

R: It was like grouping things [too strictly]. Knowledge should be seen from a larger viewpoint. Things are not like that in real life, they are not grouped [or in boxes] as the borders of departments and laboratories were there at the university. But maybe this is because there are departments in which it is either harder or easier to get accepted, so then there is a kind of jealous arguing that if a student studies a few courses here at our department, and he has not originally applied here so does this student receive some kind of undeserved benefit of it? So I think that the whole complex [studying the Master's degree] is suffering quite much from it. For instance, there at the Laboratory X, they should have put the whole group of students to study machine building even if it is at another department and students should feel it is a kind of demotion and "now we are being mistreated" but I think that would be the right way. We should see facts from a larger viewpoint--- because when you are studying there at university, you do not have any understanding what the working life is like and what you are doing there. You learn it later on. That is why I think so. However, I do understand what the meaning of the education is, to show a kind of engineering world view and what its foundations are and upon which factors it is been built up. But nevertheless, the university should take much responsibility that it should find out which subject areas belong together and how they belong together and not to try to divide them somehow. If there is a natural link between subjects and topics [in working life] so it should also be kept there at a university.

When thinking about his competencies, Gustav thinks that he has learnt Swedish, German, and English through his work and experiences. He comments on the Swedish language that *"well, in Sweden it is almost a must to talk in Swedish. I found it out quite quickly that this won't work unless if I do not start using Swedish [laughing]"*

Besides languages, he mentions business and commercial skills; the knowledge how to write offers and how to handle negotiations. He has taken some courses in cost accounting and has learnt contractual law. In sum, he has adopted most of these skills and competencies at work, learning by doing.

Definition of expertise and expert by Gustav

According to Gustav, an expert has to know his/her field and the substance and expert is a paid advisor or counsellor. He says it is the question about

knowing about some area or field; if you do not know about the field then you hire somebody who knows about it, as a counsellor to help you. He continues that an expert is a person to know the theory and practice at the same time. He mentions that he has also been in expert tasks, working as paid expert in the Baltic area giving his expertise on power plants and consulting on the generators there. He explains that in his case he had a kind of domain knowledge which the client did not have. The client had trust in him that he should take care of the project and solve certain problems in it. He finds it very important that experts have natural interest in the substance. Furthermore, he adds that they have a desire to solve the problems and not to leave them unfinished. In expert tasks, he says it helps *"when one has gone from bottom up"*. Gustav himself started as a designer and he finds it as a good starting point because in production design you have to go through many small basic details which cannot be ignored.

Furthermore, he thinks that experience has much importance in his field; the knowledge and education on that power plant technique fields is not given in Finnish higher education – people learn about the field through work. He adds that interaction with other experts helps a lot – he recalls when having worked many periods in Sweden he learnt very much about power plant technique area through interaction. He describes his thought as follows:

R: I had to stay many periods of time in Sweden in some phases of my career. It was very educative. I had to study such things that I may never have studied otherwise [unless he was not in another country]

The development of Gustav's expertise as a path

Gustav has followed a type of general expertise path (see Figure 16). He started as a designer in production planning learning well the foundations of his field. Further on, in the next job, he received additional tasks and responsibilities taking care of larger projects and their whole life-span. He has deepened his knowledge on his field during his years in working life. He believes that in the future he will need more and more project management, law and cost management skills and he would move on to more general type of tasks instead of in-depth expert tasks.

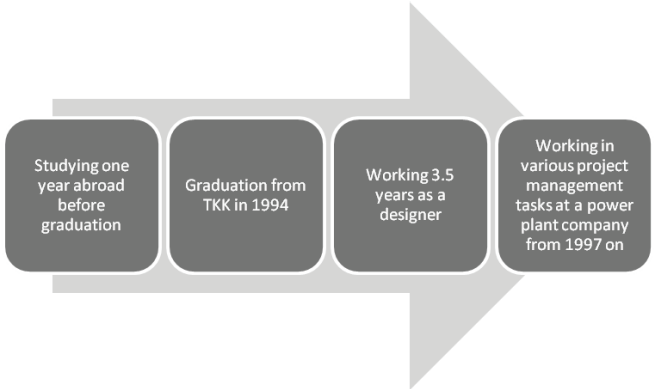


Figure 16. *Gustav's career as a figure (author's original diagram)*

The future and the most important aspects at work

When considering about the future, Gustav would see that his tasks go further into the field of commercial and business management in which he needs, for instance, more knowledge about project and risk management. He believes that he may need less his domain knowledge of engineering field in the future. When thinking about his future competencies, he expressed that *"usually I have not wanted to be a kind of drifting piece of wood, I have tried to see how I can paddle myself, to which direction I am going and which issues I should settle out—I may have always wanted that there are always some kind of challenges [in my work] – I have not wanted that I should work with the exact same tasks year after year."*

Gustav believes that one of the most important aspects for work is change and variation. He finds it very important to search new knowledge. He claims that developing something new, creating and searching new models or solving problems are also significant factors in work for him. In sum, he says that during his whole career it has been important and interesting to settle new tasks and taking them over.

R: Maybe for me it has been somehow important that there is always something new, and I have always thought that solving problems or finding new ways, or creating new, or finding new models, I have had those in my mind. Always, let's say during my whole career, a kind of settling new things and taking them over, I have always been interested in those. I am not like that I should want to do things in the same way year after year, but I have always wanted something new.

Furthermore, he adds that there is also another side in this question. He claims that *"work is always work, whatever you did, either you were a chauffeur or a managing director, but it is work, and you have to work hard. This is a kind of principle for me."* When thinking about the future, he sums that he does not speculate with facts – *"and then when I am not like that, I do not start thinking whether I had done so and so in the past. I do not speculate with old aspects at all."* He believes that what is done is done and it is not worthwhile thinking how aspects could have gone. He claims he is satisfied with his career in that sense that he has been able to develop his own professional tasks and he has been able to work quite independently.

Next respondent is Werner, the last one in the group of industry-oriented interviewees. At the time of the interview he was an entrepreneur after having worked various years as an employee at other companies. I named him after *Werner von Siemens* (1816–1892), who was a German industrialist and inventor.

Werner

Werner graduated in 1991 from TKK with electromechanics as his major subject. He has worked for more than 20 years in industry in several companies. He worked as an entrepreneur in his own company with several employees at the time of the interview.

The time span before the studies at TKK

Werner believes that his interest in engineering originates from his childhood. His father was building and constructing various 'things' at home as a hobby and Werner could help him. As he puts it, *"I could spend time with him and it was interesting to use tools"*. He also believes that his parents had some sort of stereotypes of *"respectable professions"* which affected Werner's thinking when choosing his career. He claims that according to his parents, *"there was a kind of pressure from home that certain professions were good and that is why I had to apply to the medical faculty [at the University of Helsinki] and I had to suffer that bitter defeat [of not getting accepted there]. The second option was TKK [Helsinki University of Technology]. If you had been raised up as a very good boy, then you could become an electrical engineer, or get a Master's degree in engineering, so there were these two options. So fortunately I got accepted to TKK, and the others [members*

of the family] did not have to become very disappointed. But it was a question of [academic] respect in the beginning."

Werner was very enthusiastic about mathematics in the upper secondary school, and succeeded also well in scientific subjects there. He told that he liked chemistry much and in particular physics and mathematics. He spent one year as an exchange student in the United States before matriculating from the upper secondary school. He noticed quite soon there that the level of mathematical knowledge in US schools was much lower than in Finland. He had been studying second year courses in mathematics in the upper secondary school in Finland and those courses had proceeded much deeper than the ones of American senior graduate students. Werner started studying so called 'advanced placement' courses in mathematics which were meant for the most advanced and brilliant students in the American system. He performed excellently in them compared to the American study mates. He was also very interested in programming courses and participated in the programming competitions for American students. According to Werner, *"at that time people used Basic, there was nothing else in 1979, and in 1980 I was as a representative in the programming competition between the [US] states, and that was a pretty tough thing. And then I carried home to Finland all those exercises which I had had not time to do there in the competition."*

After the exchange student year in the US he returned to the Finnish upper secondary school, matriculated from there and applied to the university. As he told earlier, his first choice was the Faculty of Medicine at University of Helsinki, and the second choice TKK to which he was accepted.

The time span during the electrical engineering studies at TKK

Werner started his studies at the Department of Electrical and Communications Engineering. From the beginning, he found studies very different and even shocking. Even though he had studied mathematics in the US, he found the university mathematics very different and difficult. He did not start the mathematics courses early enough, but completed them much later in his studies. He added that he liked the applied subjects much more than theoretical ones and claimed that he would have had much more energy to complete those courses.

When thinking back to the study times, Werner has rather bad reflections on the student life and activities at TKK. He quotes as follows:

R: I think I was given a wrong perception of the student life, in a way the guild life was overly active. I had too much party life, partying went totally overboard. I could not believe myself that I had such a desire to have fun and parties, but that I really believed that 'nobody studies anything here [at TKK]', that the life is only about having fun. I did not study for the mandatory mathematics courses in the beginning and then I got tired of studying them, and then I got irritated about it all. I had those mandatory math courses undone for a long time and I spent really much time searching binary numbers from the class board during the first year of study and I got zeroes [fail] as a grade in many exams, I got very annoyed about it. I got delayed in my studies because of that. I found the applied subjects very motivating and there in electrical engineering subjects' side I had such things in which I would have needed mathematics. In that phase, I realised that 'damn, now it's time to start studying'.

Werner believes that in that time the information about the studies and student life came from only one direction; from the technical student union and the guilds. He claims that the only info given was about the different student activities and hobbies and not much for instance about studying techniques at a university and the differences between university and the upper secondary school. He notes that afterwards he is still rather bitter about the incorrect information given of the studies. Nevertheless, he continues that *"I myself went along with it that 'yes, this is the big thing when the mainstream [of the students] does so and the mainstream goes to the parties and takes big study loans from the bank and is having fun in parties. I have many friends who did it in the same way."*

Later on when working as a research assistant at TKK, he recalls there were many students like him whose delayed studies were helped and supported so that they could complete their Master's degree in engineering. When recalling his own study times, Werner repeated again how bitter he has been about these wrong perceptions of the student life at TKK. He claimed that *"in that phase it would be really important that a smart older student from the guild (who also goes to the parties) says that 'you are welcome to the parties but do remember <u>not</u> to come on the last evening before the exam'. Then you could also get the idea that you are allowed to go to the exams, which [idea] I did not get during the first year of my studies - if everyone else goes partying, and the attitude is that 'are you really staying at home and studying, are you a loser, ok, sorry, I will also join you [at the party] And there comes the next day and it's pretty sure that you fail in the exam, you cannot succeed [when having been to the party]. I was just so childish. I pretended to look older. I even went to the military service there between and I had been*

one year in the US but still I did not have that much age in order to have an understanding which matters are really important."

When Werner had been studying for four years, he noticed that the first of his student mates, who had started at the same time, began to graduate. This situation made him think about his own studies – he was half way through them. He had a good friend who completed the Master's degree in rather a short time. The friend comforted Werner by saying *"look, don't worry, I had to graduate so quickly because I have already these children here – I have to finish the studies and apply for a job in order to look after the family. But don't worry about completing your studies a bit slower pace"*. In this phase Werner started to think about his own studies and whether he would make a type of engineer who calculates magnetic fields, of motors with computer models. He came to the conclusion that instead of that 'model' he was more interested in general management. He says that his mathematical talent was *"history"* in that phase of studies. As a result, after the turning point in his studies, he started working more industriously and completed the courses needed for the Master's degree.

Werner completed gradually his studies while working at the same time. From the fourth year of study, he was working outside the university in several companies. He also worked for a while at a laboratory at TKK and completed his Master's thesis there. Before that, when having worked for some time at a globally owned company in product development, he had asked for topics for his Master's thesis. The supervisor had promised to give a topic in time, but had not suggested them so far. To quote Werner, *"and then this offer came that I could start as a managing director in another company. Then I had to reach a decision of whether to do the thesis for the global company, or whether to search for other topics elsewhere. I had not received any topics from the company. Then I asked Professor X [at the laboratory] what I should do and he said 'come here and you will get a job as an assistant, I have a vacant job [available] so you can do what you want'—Then I resigned myself from the larger company and asked for my tax deduction card. Next the supervisor came on the very same day and said 'well, I have six topics for Master's thesis here'. So, I asked what you have there. 'Well, here the first one is dimensioning of electric drives for slitter-rewinders, and then here a little bit different type of dimensioning of electric drives for slitter-rewinders. And here, the same type which goes to Germany—they were all dimensioning of electric drives of slitter-rewinders. I replied that 'well, thank you, this seems to be interesting, but these same kind of topics have been completed long ago before me, maybe I think about it, thank you!' Then*

I accepted the position as a managing director, and at the same time I was working as an assistant at TKK."

Werner worked some years simultaneously in two different companies which was rather exhausting for him. The economic recession started to have its effects also on Werner's company in the beginning of 1990's and the company was closed down when Werner still continued at the TKK laboratory. In 1991, he completed his Master's thesis in four months in order to be able to receive a new job after graduation. To him, the laboratory in which he completed his major studies has been a type of base or a foundation in his career. Werner claims that he chose his major subject in the first place because he had heard many people speak positively of Professor X and that this Professor had his special, encouraging style to motive students into their studies. Werner adds that he completed also some post-graduate courses and thought over starting as a full-time postgraduate student. Nevertheless, due to several changes and challenging jobs in his career, he did not apply as such.

The time after graduation in working life to the moment of the interview

After graduation Werner has worked in several jobs, including tasks in project management and product development. He entered working life many years before he graduated from TKK, and has acquired more than 20 years of work experience. The latest years he has been working on quality management as an entrepreneur. Werner claims that he sees no connection with his TKK studies and his work career. He worked more with the traditional engineering type of tasks when functioning in product development. He recalls that during earlier stages in his career he did not receive any challenging tasks or positions on the behalf of the Master's degree in Engineering (compared to the colleagues with the degree from polytechnics). Werner quotes as follows:

R: I have not received any more challenging tasks in exchange, or my expected better knowledge compared to an engineer graduate from polytechnics. The responsibilities are somewhat larger when you try as a graduate from TKK, when you design something, you can. – If my title [in business card] says DI electrical engineering so it does not allow any right to speak anywhere [in comparison with the degree received at the polytechnics]. So it does not matter at all what it says there if you are not in electrical engineering.

He continues about the Master's degree in general: *"if I think about those engineers [graduated from TKK] with whom I have been in contact recently, so those people are working as business managers in companies, they do not have anything to do with currents and voltages. We should remember the fact that the basic engineering education is an intermediate phase in your career along which you move on."*

Werner claims that product development has been *"a package of skills in the fields of innovation, problem-solving techniques, motivation and even HR management"* to him. Furthermore, it has provided an immense significance in his career. He continues:

R: "It has been the driving force – [it means that] you are able to develop new working methods and develop and take care of the innovative working environment---[and] all this work that I do now is seeking for opportunities for our client organisations. Of course, it is much more but this [product development] has been the forcing drive. And [university level] mathematics, it has had no value at all. Then I have had studies [in working life] in financial management which have been very important but it has been solely self-studying. After having acted as an auditor I have said that it is no use of starting your own business if you cannot take care of bookkeeping, taxation, and these basic things, this is a kind of basic package which should be integrated in the TKK studies – I have so much experience in working life myself so all those years when I worked in company X [in ICT field], every single boss had to do his own budgets, and today bosses increasingly have to assume more diversified responsibilities. Then you have to know about HR management, financial management, and all this is required when you are leading a unit, even a smallest one. You will be responsible for business results if you work any bit in an international matrix organisation. It [including studies in business and management] should be taken care of in these basic studies, these engineers are probably proceeding in their career so that they will receive responsibilities as first line superiors, or they have responsibility for products. They should have the abilities to lead a team, or skills in HR management.

[You have to have] competencies in accounting, forecasting, and estimating the business and you have to know key financial figures. It is really bad if you are a graduate engineer and you only got some basic [university] courses in financial management and then you come to work as a recently graduated engineer and you assume your area of responsibility and you cannot even accomplish a budget. These basic competencies [are important]; I have so many colleagues who have groaned when struggling with their key figures. It is such a pain to learn these things at work."

Yet again, he mentions management skills which he claims to be important in every field. He stresses that HR management skills are important due to the welfare of employees. However, he continues that it is necessary to be able to plan and lead the functions and make decisions, or to give orders and

delegate and participate in order to manage. He adds that he could learn these skills *"very little at TKK, very little"*. He re-mentions his bitter feelings about his study time; as he puts it:

R: Look, I was a little bit blind in a way that I was taken around in the student organisations; they were interested in me, a new first-year student, they were those people who tried to recruit me into their camps by touting new members and they were not student counsellors who would have been interested in leading my studies into the degree completion. I cannot remember anyone there who would have taken such a responsibility [to guide in studies]. And I think it should have been like that as today in all schools, at least in the lower stages there are these study counsellors [for students]."

He summarises his thoughts by saying that he has received the required knowledge and training by studying and learning independently throughout his working career after graduation. He states that *"by now I would already know what I should have needed if I had studied those facts 20 years ago"*.

Definition of expertise and expert by Werner

Werner starts defining the counterpoint to expertise. He believes that so-called opinion-based experts are in the other end of the line when mentioning experts and expertise. He claims that he has met many of these types of experts during his career. According to Werner, these experts are representing their skills and knowledge by saying that they are 'self-taught', for instance, emphasising the fact that they do not have an academic background. He sees a clear difference between *fact-based* and *opinion-based* expertise. Owing to his long experience, he claims that he becomes most irritated when meeting such consultants who claim that their expertise is solely opinion-based and self-learnt. He describes his thoughts as follows:

R: --I was there at an exhibition for subcontractors with my [company's] stand so there I meet people who are starting their career as consultants. They present themselves 'self-taught'. Or, they are consultants, they have business cards and they do have a team also, they present themselves as 'self-taught' as if it were a virtue. And I am horrified of this style of thinking that self-taught people whiz around 'the cape' of Finland consulting real entrepreneurs who have all their money invested in their companies how the business should be lead, what kind of decisions should be made, or what solutions should be done, all this based on [their] self-taught expertise. If all this was based on expertise I wonder whether the world was different. We could get these self-taught persons out. A stamp into

your forehead "I am self-taught; don't believe in me, [all I have to say] is based on my own thoughts [and not on fact-based expertise].

Werner continues describing real experts: *"But then when you are an expert, you have some field or branch mentioned in your business card or a mention how you have gained your expertise, isn't it so, some book learning is also included in there. And then one's [expert] micro world opens up beyond your personal experiences. This is just how we respect the [academic] studies –we come and complete further studies at TKK, we attend the courses so we are searching for something which someone else has learnt, and then we will become experts."*

When thinking about his own competence development (see **Figure 17**), Werner says that he needs to update his skills in management; there is always a need to learn more in that area. At the moment of the interview, he was completing a special professional diploma in management organised by an external private organisation. He claims that the Master's degree in engineering carries only halfway in one's career; there is a need to acquire more substance and training in working life. He wonders whether it is possible to integrate the knowledge needed in working life into the current engineering education.

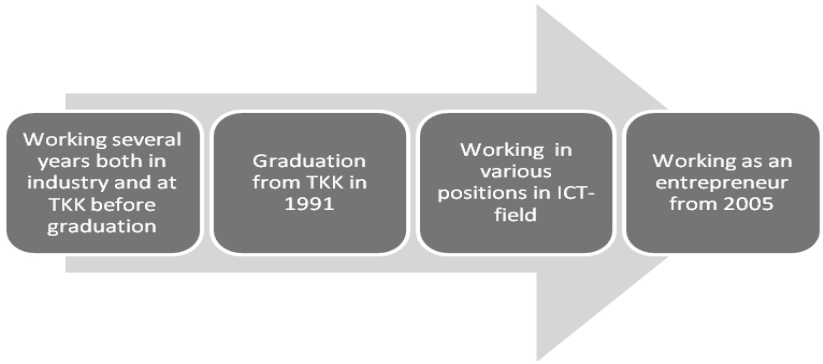


Figure 17. *Werner's career as a figure (author's original diagram)*

The future and the most important aspects at work

Werner sums up the difference in his thinking when comparing the time when he began his career. He states that in the beginning, it was very important to him to achieve something visibly acknowledged, or that your achievements could well be noticed by the others. But now he says that the

important thing is the significance of the work. He mentions that the importance is changing its character; it changes into a more intangible type of significance. He says that it is natural that he wants to have respect for what he does and that it is important to enjoy what you do. Furthermore, he mentions his current field; corporate social responsibility in which he designs long-term scenarios for the business of his client companies. He plans and designs visions for their corporate social responsibility and has the feeling that *"when I can affect their lives, it is extremely valuable for me that with my own actions I have larger societal effects which can be beyond measure."* He describes some examples of his client cases.

He continues that *"then those societal disadvantages [which could be] discharges, energies and so on, [companies] being able to recycle something plus all the other benefits and choices which companies [clients] do in the planning stage, [all this] cause such a large final significance to the society. So then [afterwards] somebody [client] says that 'we did this in year 2008 when that Werner X said that it would be good if you chose that kind of planning parameters' – so there is this small awareness what I can do now [for the future] than to enjoy the respect I receive on a daily basis at work. It goes a little further in spheres. I really enjoy that kind of aspects. I have been able to affect the companies' growth to the next stage in which they are ready to do what I am suggesting to them. And then I really don't want that some of those self-taught experts go there and say that 'because I feel so, you know, it should be sexier to pay more attention to the energy consumption levels, you can design, for instance, more energy-efficient equipment because I feel so'. They [companies] blindly follow the only advice they have got, and then they forget something else, for instance, safety issues, or something else. In there I can see the significance of refining your own expertise."*

4.3.2 Research-oriented work narratives

The following four narratives were all gathered from university and research-oriented context. Two of the respondents were working at a university, and two at a research institute. Three respondents had more than 10 years of work experience, and one approximately five-six years in working life after graduation. In general, these narrative stories represent two types of characters in research context: a 'pure' researcher, and a combination of a teacher and a researcher.

The first respondent in this group is Ada. She was named after an Israeli scientist *Ada E. Yonath* (1939–), a Nobel Prize winner in chemistry.

Ada

Ada has acquired a scientific career as a researcher at TKK. She has worked both as a researcher and a teacher. She has acquired approximately five years' work experience after her graduation which makes an exception to the other respondents in the interview. The rest of the respondents had a minimum of 10 years work experience after their graduation.

The time span before the studies at TKK

Ada was very interested on mathematics and physics in the upper secondary school. She told that she had had very good teachers in both subjects already in the lower stages at school. She wanted to continue studies straight after her matriculation, and she was looking for different options where to study. She said that she chose TKK as the first option but emphasises that she did not see this as the right and only one.

R: "But I could not see this right and only option in any phase – in a way, I could have drifted to some other place [to study] but I have not regretted it, I have enjoyed very much here [studying at TKK]"

She tells that she did not know any women in engineering, or engineers at all before coming to TKK. She also emphasised the fact she comes from a working class family in which the mother and father were not academically educated. She concluded that she did not have any persons in mind as a role model for university studies. Somehow she had received a clear idea in her youth that she wanted to study at university. When asking her about being a female at TKK, she said she had not thought about it at all. She had thought it to be a kind of irrelevant question. When she started studying at TKK, then she actually noticed how few other girls there were. She told it was not difficult, but however, the small number of women was a kind of surprise for her.

The time span during the electrical engineering studies at TKK

Ada started her studies easily. She was studying industriously the first year according the model schedule. One important thing to her was that she got acquainted with other students who were much alike her. They were all interested in studies, and they did practices and lectures together. During her third year of studies, she became interested in her main subject and chose her major. She received a summer job at the same laboratory, and noticed how interesting the subject was. She told about her Master's studies as follows:

R: The last years of study [completing the Master's degree] were, let's say, quite fun and nice, you had the basic knowledge in a way, and then in the other [more] applied courses you started to have the same things. So, they supported each other, and they [the topics to be learnt] started to be in larger units.

The most important thing which affected her studies was that she found a good friend which whom she did most of the studies and practices together which the she found very motivating and fun. She added that she had used to work much in the upper secondary school; she was used to it and she did exercises with pleasure. Ada admits that she did not participate much to the lectures. She had noticed that she learnt best when she performed studies by herself. Furthermore, she adds that she had difficulties in concentrating on the lectures, and could not learn much out of them. However, she did not take much stress on that because when entering TKK she recognised the most optimal way to learn for herself. In addition, she emphasised that it was easy to start at TKK and get accustomed to university studies because from the beginning she made the acquaintance to such people with whom she kept together through the years of study [interested in studying, doing exercises together]

From the beginning, Ada's aim was to graduate from TKK. She had decided that she would not leave her studies unfinished, or begin to work outside the university too much. She had had a job as a supermarket's cashier during the first years of study, and it helped her to receive more motivation in studying. She graduated in due course and added that she did not have any special own expectations or prejudices because she had no previous engineer role models. After she had received the summer job at the laboratory, she also acquired the topic for her Master's thesis from there. Furthermore, this offered her a chance to continue as a postgraduate student at TKK.

R: And then it went that way that when I had finished the Master's work so then our professor told me that if I am interested, it is possible to get funding for postgraduate work. And maybe in that phase I did not even find out about any other options. So then I was just "this is ok, that's fine, it sounds good to still stay here at TKK--- to continue as a postgraduate"—and maybe that time it was a little bit, though it's not so long ago, so there were that kind of economic fluctuations, at least in this field within the larger employers that you could not get actually… [get a job] There was a kind of ban on recruitment that time [in year 2003]. So that time, if you wanted to get something else, then you should have really wanted to have it and get out from here [TKK] and go and find the other possible options. And then, when I started here, I had not thought about that I would like to continue till doctoral dissertation—that it has been a matter of chance.

Ada was rather satisfied with her studies at TKK, and saw her major subject together with minor subjects a *"good package"*. She finds her own field as a good traditional engineering field which is long-standing and respected with traditions. According to her, these traditions supported the good quality of teaching at her laboratory. She described some examples that there are courses for basic students in which there is a varying substance on the latest research results or topics.

The time after graduation to the moment of the interview

Ada started her postgraduate work at the same laboratory where she had worked earlier as a student (see **Figure 18**). The first couple years she was very motivated and her post-graduate studies went fine. She completed the courses for the doctoral degree and started the research work. But then the years after the beginning started to be difficult or hard. According to her opinion, her work did not proceed well and she could not receive sufficiently guidance or support to her research work. She was not a part of any research team, and she had difficulties with her thesis subject. She also told that it was not usual that researchers worked much in teams at the laboratory where she was. The year 2008, when I interviewed her, had been much better for her. She had received more support and guidance, and she had acquired more motivation, and assumed that her thesis to be finished in a good time.

The major supportive thing in her work has been teaching. Professionally, it has been a positive thing in her career. She has learnt much of herself when she has been teaching students. She describes the function of teaching as follows:

R: But it [teaching] has not only been a bad thing, it has been a really good thing professionally. However, it has taken horribly much time—and of course; it is your own choice that how you check student reports, how much you invest your time on each thing. But this [teaching] is maybe a thing I regard as a very important function of this university. In its scale of functions, it has to be taken care of enough vigour--But sometimes I have been not happy about the thing that even if you had been asked, the amount of your teaching work was not reduced.

Ada described that her tasks in teaching and research work have supported each other very much. She has taught laboratory exercises for students in which they have made measurements on the substance of the topic she researched.

R: It has been very instructive [for me] to research the basic phenomena with the students in the lab. It gives me much more when I think about those issues with the students, and when they take the examples themselves, and they think those things in the other way. So it is very instructive for me, and through this [the teaching work] I have received [content] very much to my own work.

When I asked about the competencies needed in her current work, first she mentioned a good basic knowledge on mathematics, physics and on electromagnetic field theories. Then she continued with a kind of abstract competencies as persistence and initiative, and organisational skills. She also regarded the comprehensive understanding, a holistic thinking, very significant. When she has been performing independent research work, she values the skill of setting priorities and timetables for one's work. She has found that skill very significant in her earlier work phases:

R: It is, these schedules or timetables, so that you would make yourself a schedule, and you would keep in that and if you don't, in a way you could get support or guidance for those things which are not going right. I feel that I am most annoyed that these schedules were not difficult for me earlier but in this research work when it slipped too lonely [a work] from the very beginning. And then it became rather difficult in setting kind of intermediate goals, and keeping in them. This is a kind of thing or skill which I have not been able to control well enough although I feel I have been able to do it before. This is a kind of thing I would like to be able to do again, that I could monitor better my own work.

Ada described that her working conditions would be excellent if she had a team or a group of some colleagues with whom she could share her concerns on the subject. At the same time the group would give support, for instance, in monitoring one's own work load. She tells that she has learnt much persis-

tence and tolerance with not succeeding in when her research career was not as she expected it to be in the beginning. She added humorously that she is learning all the time, and especially about herself.

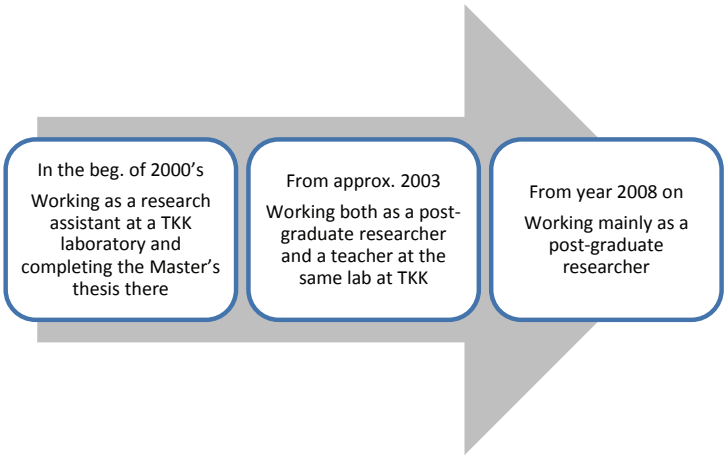


Figure 18. *Ada's career as a figure (author's original diagram)*

Definition of expertise and expert by Ada

According to Ada, expertise consists of basic knowledge which has to be good enough. It also contains larger units, holistic thinking in one's own field. Expertise is also a question of understanding and accepting the fact that there's not a sole unambiguous and straightforward solution for everything. To Ada, it is the knowledge of one's own field and also an ability to adopt rather easily new knowledge. Furthermore, she adds that it is the knowing the possible restrictions and possibilities. According to her, expertise is a general competence of comprehension of what is possible and what is not, in one's own field.

The future and the most important aspects at work

At the time of the interview, Ada had positive thoughts about the future. She said that she has an open mind to various alternatives what to do after the doctoral dissertation. She has enjoyed working at the university but she could also work in the industry, or either at the universities of applied sciences. She revealed that she is missing different type of "surroundings". She would like to extend her field mainly due to not having worked in the industry and acquired that type of previous work experience. To her opinion, she

mainly wishes to learn a way of doing tasks differently. Ada had also thought about further studies in order to adopt another point of view. However, she added humorously that she would not like to stay as a student forever – in that case without any money but even more academic degrees.

The next respondent in the science-oriented group is Marie. Marie has worked mainly as a researcher at a VTT (Technical Research Centre of Finland). When choosing a pseudo name for her, I named her according *Marie Curie* (1867–1934), a physicist and chemist who was the first woman to win a Nobel Prize in Chemistry.

Marie

Marie has created a scientific career as a researcher at VTT after her graduation. She has acquired approximately 15 years of work experience after graduation except two periods of maternity leave. Some months after the interviewing moment she changed her work environment into a governmental office. However, Marie was working with the same type of tasks as earlier.

The time span before the studies at TKK

Marie said that she had always been interested in technology, machines, and equipment when she was a child. She assumes that it may have an effect that both her father and grandfather were engineers, and similarly her mother was an architect so she knew about TKK as an option to study. She remembers that at school she was never interested in languages or sales, or marketing, or aspects connected to them, such as money. Marie knew about TKK as an option to study but she said that technology itself has been the most interesting thing for her. In the upper secondary school she had large courses in mathematics and physics. She applied only to TKK and did not consider about any other options. When she applied, she was accepted in the first time. She did not intentionally apply to ECE but looked for the grade limits in general when applying. Marie told that she was interested in power and energy issues already when she was a teenager. She told a small anecdote that she was about 15 years old; she had seen some television programmes on energy production which had been most interesting, and confirmed her earlier perceptions of the field.

The time span during the electrical engineering studies at TKK

Marie enjoyed her study time at TKK and considered it interesting. When studying, she had simultaneously an active sports hobby in which she was competing much and she also participated in the competitions. She said that once in a while she was quite much away from the university which was possible because of the nature of the studies [academic freedom]. She was very content with the freedom to choose to do the studies in one's own schedule, and with the freedom to plan one's own pace of life. When Marie had applied more randomly to the Department, choosing the major and minor subjects she did knowingly based on her own interests. She had not been quite content with the overall quality of teaching at the Department and, for instance, with the professors of the subjects. But however, after having been in working life, she is content with those major and minor subjects she had chosen. Marie mentioned that in some fields or laboratories there were students who had been interested in the very subject from their childhood (radio technology, electronics, for instance) which could be seen in their deep passion towards to the subject. She did not want to choose the same subjects because she felt she would never want to compete with those students while she felt she was lacking that same type of deep passion she recognised in them.

R: In some fields there were students who had had the field as a hobby since their childhood, and I felt that I would not manage with them as much or hard as I could study. So it was not worth of going to those fields, for instance, radio technology, or electronics.

As a reflection of the studies at TKK, she would have preferred to take more courses in oral and written communication skills. She recollects that there existed one mandatory course on that subject for all students in technical field. Hovwever, according to her, that was not at all sufficient. She describes her thoughts as follows:

R: Here at TKK you calculate and measure very much, at least I gather it was so that you could have passed through the whole education as almost mute and nearly almost unable to write, well, however being able to read, because you just calculated and were kind of silent there. There could have been something like ethics and scientific thinking, at least one course… where people could talk about these things so that could have been something additional. The teaching [at TKK], well, it is quite "clinical" there in that sense. You just perform calculations or exercises, and go to the exams but no one says "hello" or "goodbye" or "how are you?" to you or "what do you think about this?"

The time after graduation in working life to the moment of the interview

Marie was interested in research from the beginning when she went to work life after graduation (see **Figure 19**). She said that she had always been interested in facts, not tasks concerning personnel, sales and marketing or such fields, but to work directly with the substance and theory itself. She started as a summer trainee, did minor reports and gradually continued to larger ones. She mentions that she has not had any special or great 'turning points' or transition phases in her career. She describes her career path as follows:

R: It is rather, how should I say, [there are] no special turns, just forward and more, deeper and better [into the substance] and so on. But there are some points which have affected the field, for instance, de-regulation of power markets, preventing climate change, and such issues… This field has faced many great changes which have made it much more interesting… the 1990's has made it much more interesting than before.

Marie thinks that her interest towards research work started during the studies. She was interested in research tasks or some kind of development work, for instance, product development. She claims that she primarily learnt her work and its substance in working life. Furthermore, she adds that learning in higher education was mostly learning by heart, not understanding the knowledge – her target was mainly to pass the courses and to go on to the further issues. She stated that the most beneficial dimension for her was an ability to search knowledge, what specific knowledge there exists, and from where to find it. After the studies at TKK, Marie learnt to recognise the ways for knowledge management through courses she took when she was studying. She has recognised, for instance, to know certain ways of calculating facts, and she has re-learnt them in working life.

R: Primarily you learn knowledge at work and that is true. Studies at TKK, they are just there and at least during the studies I felt that I only tried to perform the courses, once in a while I forgot that it would be great to learn things but you just wanted to pass the courses. You plugged in something by heart and then you remembered it for that one day, and then you forgot it again. What was maybe the most useful thing in the studies was that you learnt to find [knowledge] and know what kind of knowledge there is and how to find it. Now afterwards in working life, I have noticed that there are many such aspects which I have faced at work that I need to do something, to calculate, to solve, and then you remember that we had a course like that and such matters were handled there. Then I dug it

out [the course material] and then you finally understood it just when you knew you needed it at work.

Marie describes herself as an expert with a wide area and scope. She used an analogy "grocery store" when talking about her own expertise. She describes it so that first of all, she can quickly adopt new knowledge and produce text, calculations, and results. She has a pretty good overall picture of the field, sufficient wide scope. Moreover, she knows which facts belong to which context, and she quickly knows what is relevant and what is not.

R: When you have been performing research work for a long time, and if you are able to see facts with a pretty wide scope, then you learn rather quickly to outline and see that, aha, that thing is dependent on that and this is very important and that is not and which is an unessential point, what is not.

She claims that her expertise has developed towards a rather wide direction. She believes it is both good and bad at the same time. The bad side is that she does not know much (or very deep) about certain, specific areas. But she emphasises that she has deliberately selected this wider scope.

As a kind of turning point in her career, Marie mentions a working period in another bureau when she was on leave from her permanent job. She stated that the period was a very good and interesting one. She adds that it would be very good for one's development in expertise that this type of system would be possible to circle in different tasks in order to enhance one's expertise. Furthermore, Marie mentioned that it has been a positive thing to work in multi-disciplined teams, for instance, with economists, and lawyers. She says that *"it opens well your eyes to meet people from other fields [disciplines], in research world we are mostly engineers, and there you easily assume that everybody else in the world thinks like us".*

Marie tells that the gender (being a female) has not had much effect on her engineering career. However, she describes that in electrical engineering once in a while there are older men *"who know how things are, and how they have always been and 'so shall we do', and 'oh dear, those younger ones do know not anything, and especially women do not know anything' and if I say that things are like this and these are the results so it is just so that "oh well, is it?"* or *"could it be like that?"* But she says that in general she has met quite pertinent behaviour, although there have been some minor doubts towards her expertise. In general, she concluded that her gender has not affect-

ed much her career. For instance, she has often been asked to take managerial duties but she has denied because of her greater interests in research.

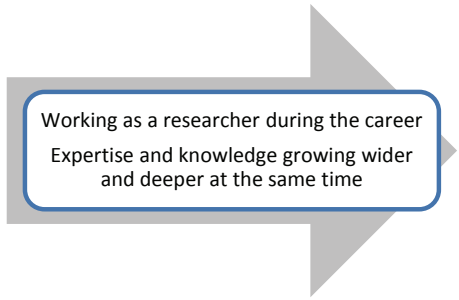


Figure 19. *Marie's career as a figure (author's original diagram)*

Since her graduation in the beginning of 1990's, Marie's career has gradually started growing towards a wider and deeper expertise without having any significant turning points or transitions phases in her career.

Definition of expertise and expert by Marie

She started to describe expertise with importance of knowing much about one's own field and importance of being aware of what are the matters, or fields one does not know much about. She described that people often identify their own specific area but do not know anything about there around it. According to Marie, real expertise is to know that much about everything that you know about the related aspects and you can locate your own special knowledge. To her, it would be most important to be aware of all of existing knowledge which one does not know about.

According to Marie, expertise is being developed only "*when you are interested in facts, to have your eyes and ears open, and you are in contact with people who work with a little bit different facts [than you], or see aspects from a different point of view. And when you read, and that you do not categorise yourself, close out everything which is not related just to your own field but you are explicitly interested in everything which is close to you, or is related even a bit, or so. [It means] that you are truly interested and want to know about your "neighbour" [at work]*".

The development of Marie's expertise as a path

Marie describes her own expertise as quite broad. She has knowingly chosen her own viewpoint. She added that she has discarded the idea of having some specific area in which she has her own expertise. She has had a researcher career, but not at a typical university environment (to complete dissertation, and after that, to continue as a post-doctoral scientist). According to Marie, the engineering studies at TKK have well supported her decisions and expertise growth in her career.

The future and the most important aspects at work

Marie regards that the most important thing to her at work is to have interesting tasks. Furthermore, she added that good colleagues are important as well, or vice versa, it would not be nice to work with unpleasant people. Another side to the interesting tasks is that she enjoys that the tasks, reports, or results she produces, are needed by someone. In another words, it would not be motivating to perform such results that nobody would in fact require or use. Thirdly, she mentioned that the atmosphere at the working place is important; it is essential that she enjoys coming to work every day.

From Marie, the stories come back to the university context. The next respondent is Simon, who is a professor at TKK. I gave him the pseudo name according *Pierre-Simon de Laplace* (1749–1827), a French mathematician who invented Laplace's Equation and Laplace Transform, which belong to the very significant substance in the electrical engineering.

Simon

Simon has graduated from TKK in 1987 and has had a scientific-oriented career at university since that. He has been working with various tasks in research and teaching, and during the recent years as a professor.

The time span before the studies at TKK

Simon originates from the Finnish rural area, and his family had all types of machines and equipment at home, which he used to build and repair when as a child. His father worked in technical field tasks with many engineers as his co-workers. Simon regards his father as a role model for him.

At school he was interested in mathematics, physics, and chemistry and at the latest in the upper secondary school he became interested in applying to a technical university. Simon recalls that at least six of his classmates from his own class applied to various Finnish technical universities (TKK, Tampere, and Lappeenranta). He claims that they did not decide intentionally to apply together but were probably affected from each other's decisions. He also applied to University of Helsinki to study natural sciences and got accepted there but he was more interested in studies at TKK, and chose to start here.

The time span during the electrical engineering studies at TKK

When entering at ECE, Simon met with a group of students in mathematics lectures and practices with whom he started to study together. The first autumn term was *"a shock"* for him when he studied together with the whole group of first year students. He describes his feelings as follows:

R: Well, the first autumn [term] was a kind of shock for me even if I had not imagined being among the best ones in the upper secondary school but then when I came here [TKK], I heard that everybody had six laudatur. So when I was talking to someone here I was wondering how to manage here when he [whom he was talking to] did not have those six laudatur---then it was not the question of how many laudatur you had- but [it] did matter that you had entered here, and your own learning style mattered.

Simon studied industriously from the beginning and followed model schedules each year. Being in the group of students which was formed in the first term helped and supported his studies much. However, he still had time for hobbies each week and he participated in the activities of the association of his major subject. Simon was among in an active student group organising a longer study tour abroad and collecting funding for it. He also wrote and edited a book with the student group. In brief, he passed his courses in a comparatively short time [in four years] and completed his Master's thesis at the laboratory. He was asked to work as a summer trainee at the laboratory by one professor. This slowed down his studies as he worked on the Master's thesis at the same time. He describes the period of completing the Master's thesis as follows:

R: But then I did, a kind of mistake in parenthesis, I came to work to TKK as a summer trainee when one professor began to ask me, and that slowed [his schedules] a bit, then when I also was an assistant, so it took me two years of calendar time to do the Master's thesis, even if I had been [here] four and half years, then in 1985 I could have finished it [the degree] if I had completed it sooner. So I would

have finished my degree, well, under five years, but there came all kinds of things in assistant work and other stuff incredibly much, and the Master's thesis was to build educational equipment which took much calendar time---Well, it was quite an intensive time period, and then post-graduate studies took some time, I did not start them immediately.

The time after graduation in working life to the moment of the interview

Before graduation, Simon started to work at TKK, and completed his Master's thesis at the laboratory where he had studied his major subject (see Figure 20). He completed his Master's degree in year 1987. He was working as a part-time assistant, an assistant and as a senior assistant. He completed doctoral studies also at TKK and he has been working here during his whole career. A few times he has been wondering whether he could work somewhere else. He has applied jobs elsewhere (outside the university) but each time decided to stay at TKK because of available positions there.

Simon has concurrently been working in research and teaching tasks and describes his tasks very varying as follows:

R: Except this last half-year period, I have been working in the same type of tasks, well, of course they have varied from time to time, it has always been teaching and research and then, in the meantime, I have been doing everything possible what people do here at TKK: starting from secretary's and laboratory engineer's tasks to making coffee, acquiring projects, teaching, producing course material, everything possible.

Simon sees a clear and coherent connection between his studies, the Master's degree in engineering, and his career in working life. He states that they are actually inseparable although he mentions the first years' studies might not have been so useful. Nevertheless, he mentions that there are topics, for instance, general knowledge and some technologies, which should be gone through and re-studied in order to better use them in his work.

One of his strong competencies is a good knowledge of his own field. Furthermore, he mentions that he has received good qualifications to become a researcher and to supervise scientific work, starting from supervising Masters' theses to doctoral dissertations. Likewise, he mentions managerial and administrational skills or competencies, and assumes that along the years he has developed in those. As well as these competencies, Simon mentions par-

ticularly teaching and pedagogical skills. During his career he has been very dedicated on teaching tasks. He ponders that there are no further limits when developing one's skills in teaching and in research tasks.

R: These are all that kind [of tasks] in which you cannot be fully competent, as a researcher you can always [develop yourself], there are no upper limits, even in your own field, and then you could think a little about how you could extend it [skills]. Well, as a teacher you can always critically think about [your] teaching methods and other dimensions what you can adopt just if you had enough time and resources. That is, well, an endless field, as well as developing oneself as a superior--- you should search and find other practices and methods, in that sense to train oneself more..

He sees that there are some major competence areas in which he would like to develop. One of the key competences to him is time management. Due to his tasks he has had tight schedules. He wonders that to develop oneself in time management, he would actually require time to have a break and think matters over, for instance, how to perform tasks differently and more efficiently. As an example, he mentioned a certain computer software programme which would help his work load by transferring data from a computer to another one. He had been working on it without succeeding in to get the systems function. Information and software using skills is an example of another competence area which he mentions as important to learn. However, he notes that despite how much one could get developed in that field; there will be certain limits for the development because it does not belong to his main tasks.

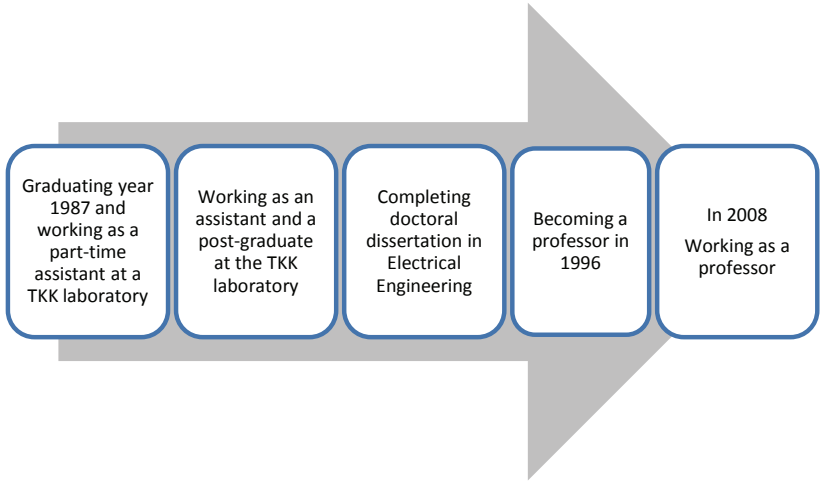


Figure 20. *Simon's career as a figure (author's original diagram)*

Definition of expertise and expert by Simon

According to Simon, a scientist is always an expert, but experts are not scientists. Furthermore, he emphasises the cumulative experience which supports one's expertise. Moreover, he adds that there has to be knowledge through studies. However, the major element according to him is experience and diversified views. Expertise can also include a notion of scientific knowledge and thinking.

The development of Simon's expertise as a path

Simon regards his own expertise dependant on one's personal character. One professor may claim to be a 100% expert in one's own field and another colleague may say having only 50% of expertise in his field. He estimated himself to be somewhere in-between these two examples. He continued that experts do not have to know everything, but the importance is on the good ability to adopt, learn and search more information. He claims that it would be quite impossible to know thoroughly one's own field. Furthermore, he quite self-critically adds that defining one's own field is a rather indefinite task. It is dependent on how concise or wide the viewpoint is.

R: And then when the definition of your own field is rather vague that what do you see included in [it], how concise you see it, in some fields you can well know [the limits] but then when you go further away so then there are some points which are definitely not in [your] control.

The future and the most important aspects at work

According to Simon, one of the most important aspects is motivation and enjoying one's work and career.

R: Maybe it is anyway so that it is fun to come to work in the morning, well, not always but principally, that's how it is because otherwise then you should consider changing your career, or your tasks.

Simon mentions teaching as one of the most important aspects in his career. He wonders about the word semantics when using the word 'teaching' and suggests that it could also be called 'organising education'. According to him, it is not possible to teach anyone if the person does not want to learn.

Furthermore, he mentions research as one of the most important dimensions. According to him, research cannot be separated from teaching.

> *R: It is important to be within this [in teaching and research], or maybe people have many reasons why to work here at a university, but this is somehow a kind of process through which young people are going so maybe that's why it has been important to me and why I have enjoyed [working] here then.*

From Simon, we will come to Jacob, the last respondent in the group of the research-oriented interviewees. He was named after *Johan Jacob Nervander* (1805–1848), a Finnish physicist, poet, and meteorologist. Jacob has had a very successful career, during which he has used the substance learnt at TKK and created competencies and skills in management, HR, and other general fields.

Jacob

Jacob graduated from TKK in 1987 and has had a research and scientific-oriented career both at university and at a research institute since his graduated. He has been working with various research-oriented tasks. At the moment of the interview, he was a vice president and a research professor at a Finnish research institute.

The time span before the studies at TKK

Jacob remembered always having being interested in technology and engineering. In his childhood he was playing and building with Lego bricks[1] very much, for instance, installing electric motors to the Lego constructions. Since childhood, Jacob knew that combining electricity and mechanics would be his field. He recollects that he built a robot when he was approximately 10 years old, although he described the robot not having much electronics. This childhood hobby and play of his made him very interested in electromechanical machines and robotics. Quite early he knew he would like to study electricity and electronics yet he was also interested in studying physics.

Jacob knew he would apply to the Department of Electrical Engineering. He recalls that his mother had collected his interviews when he was seven years

[1] Colourful interlocking plastic bricks, originally Danish production

where he claimed that "he will be an electrician". He may have received influences from his family. He told that his uncle was an electrician who brought him electrical supplies and talked with him about electrical *"affairs"*. He had also other role models for his future career. His father was working at Helsinki University as a researcher, and another close relative of his had completed a doctoral degree in social sciences. Before applying to TKK, Jacob knew that he would like to pursue postgraduate studies and complete doctoral dissertation. The other academic degrees (Master's and Licentiate) would just be intermediate targets for him.

The time span during the electrical engineering studies at TKK

Jacob applied merely to ECE He had a compact and comparatively short study time at the department, altogether 4.5 years. He participated actively to the lectures, went regularly to the exercises and recitations and did a lot of homework as well. His basic aim was to complete his studies rather fast.

R: Well, my study time was rather compact and what has stuck in my mind that it took rather much time during weeks; there were many lectures, and problem-solving sessions till eight o'clock in the evening, so I felt, about lectures and practices, there were much of them, it was a huge amount [of work] besides laboratory works. I completed the degree then in a little bit over four years, in 4.5 years, and the aim was to do the first studies quickly, mathematics and physics and these, and then get to the real substance. But it has stuck in my mind that there were a lot of lectures, and those practices I did in the evenings."

Jacob did not work much outside studies during his studying time. He came from the Helsinki capital region and lived with his parents during the study time. As a consequence, he did not spend much time in the student life activities. Besides living outside Otaniemi campus area, he had a steady relation with his girlfriend also during the studies.

When working towards the Master's degree, Jacob knew all along that he would like to continue into postgraduate and doctoral studies. He remembers that he never had times of doubt where to continue next; he knew what he required. He chose radio science as his major subject in his Master's degree. He had also considered taking applied electronics as his main subject but did not choose it because of its apparently lower [scientific] level. He had acquired an image that radio science [and research in radio science] being in a high scientific level. Another factor was that radio science and technology was

closer to physics than applied electronics, which was rather important for him. Jacob describes his study time that *"it went like being in a tube"*.

When reflecting the education in general at ECE, Jacob says that the quality of the education altered really much. He mentions two professors (one in circuit analysis and another in electromagnetics) who were extremely good teachers. On the other hand, there were those who were rather poor and he could well notice the difference in the quality of teaching. When I asked about how to enhance the quality of education from that time, Jacob mentions the need to increase the general interest of students into the studies. As one means to that, he mentions, for instance, using smaller teaching groups. During his study time, there were mainly larger teaching groups except in the laboratory works.

Jacob could be considered a deep learner (or a learner with a deep approach) because for him learning has been extremely important and as well as the substance itself. He describes his thoughts on this topic as follows:

R: Maybe the kind of learning itself has been awfully important for me, it is a part that if you just learn, whatever you learn so that is important. Somehow--- studying, learning, it has always been a motivational thing, maybe it has been there.

The time after graduation in working life to the moment of the interview

After the graduation, Jacob started working as a researcher at a research group in one of the laboratories at TKK (see Figure 21). He recalls this time as a researcher as his personal growing experience which is connected to functioning as a team member. He adds that *"in that team I grew up from a young person to a researcher and it was a straight continuum to go on with the dissertation"* He continues that the research group was international and its aim was to complete something unique. The team leader had good international contacts in order to better reach those aims. Jacob considers that internationality has always been a significant part in his career. He has been working abroad for several periods, mostly in the United States. He has well proceeded in his research career having had many good positions both in Finland and abroad. He has been a research manager from the 1990's, and also been nominated as a research professor in the late 1990's. Jacob sees that his studies and his career in research have been very much related to each other.

R: Well, yes, they [studies and career] do relate much with each other, the Master's degree and what I was doing in the Master's thesis. Then my own professorship was connected with it, so if you could say, rather "dry" career in a way because it has been much the same [the same field from various viewpoints]. And if I think what I am doing now, it corresponds to all that electronics what is being done there at the former ECE, now it just has been widened. But the point in the basic degree; it was really a good opportunity for growth [as a member in the research team] and it particularly gave a kind of qualified, scientific, international, and networked way of doing things which is important now, a normal way of acting or working.

Jacob regards human resources management (HRM) skills are emphasised in his work tasks. He has been studying or learning those skills, and he considers them very important. Furthermore, he finds that competence development very important – he regards that he has acquired a good education in that respect at TKK, and the research group offered good skills for that as well. Thirdly, he mentioned functioning in networks as an important competence. Finally, Jacob mentioned internationality again. All of these skills have been essential in his career. When graduating from TKK, he had learnt very little of these. They were still seeds at that time, and were developed during his career in working life.

R: Yes, I have been thinking about this sometimes that if I should explain somebody what I am able to do…Well, HR management skills are being emphasised in this work, it starts from there and I have been studying them more, [they are] important. And then, there is this knowledge development, that is one, maybe in this connection I feel I got good education for that and the research group X was good education for knowledge development. Another thing was a kind of functioning in networks, networking, those dimensions I had. HR management, knowledge development, and networking--- The research group gave pretty good abilities for those; these are those main points if I do not include these technological issues…

Maybe these were the three things – these were the things I did not have at all then when I graduated with Master's degree, or then there were some sprouts of them but not much. And maybe the international activities, that is still missing from the list. Well, these issues [are] really in which I have developed and they have been developing at work and which I have needed. There is also the knowledge of scientific work but, let's say, these are more tools for doing and organising scientific work.

When thinking about his future career, Jacob finds that he would most require financial skills. He adds that he has received very little training or education in those. He mentions HR management and HR skills once more as an important area to be developed in his future.

Due to the fact that his career has had a constant focus (doing research work in different positions, as a researcher, as a post-doctoral researcher, and in managerial tasks); he has not had any major transition phases in his career. He has easily adapted into international environments and without difficulty has been able to work in various places. He assumes that it might have been somewhat different if he had worked in the industry instead.

Jacob evaluates that there has been some major phenomena affecting researchers' work. First, he mentions customer-oriented actions in research, and also working in groups. In addition, he adds writing joint articles as an example of a resource. During his research career, working in groups and co-authored articles have become more common. He comments on them:

R: It is a resource, and in fact, when I am doing [them], it started to be so that if a dissertation has joint articles, it is not a weakness but it is strength. [This means for example] that if there are only articles written by you [as the sole author], then when applying for a job, employers might look that this [person] cannot co-operate with others.

At this point, Jacob anew mentions networking, now as a phenomenon. He mentions that it started to grow and have an importance in research work. He returns to the idea of customer-oriented action which has begun to be more significant in research as well. He describes it (in his work context) as a requirement to understand it, to understand aspects from the customer's point of view. He describes it as follows:

R: Let's say, it has been a some sort of need in your own work, understanding customership, to see facts from the customer's viewpoint that you do not only offer your own substance but you aim to see what needs and problems customers have and then try to find a solution. That can be something and that's the direction into the world has changed.

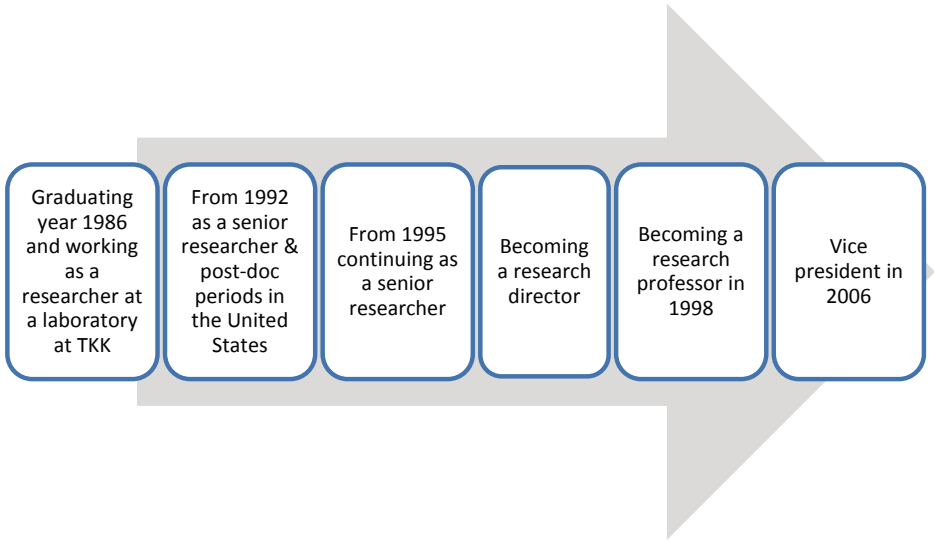


Figure 21. *Jacob's career path as a figure (author's original diagram)*

Definition of expertise and expert by Jacob

Jacob regards expertise as an indication of deep knowledge within some certain field. An expert can widely use the knowledge what s/he possesses on the field, and can apply it in different and varying cases. He adds that experts do not always have solutions but they know their field and they are able to use the knowledge and exploit it. He mentions that one of the working methods in expertise is scientific thinking, its methods and ways, which are based in logic conclusions and facts.

Jacob evaluates that there are certain changes and new phenomena that can be distinguished in the world of scientific research. First, he emphasises the scientific level of quality which has risen during these 20 years he has been working. Furthermore, he stresses that it is not enough to be just a researcher but to be a researcher at an international or at a global level. He estimates that the research at TKK previously may have been both at national level, and at international level. But, he states that today all research in Finland should be at the international level. There is no importance of performing national level research and results. This affects automatically the number of journal publications (impact factors) the importance of which has increased very much lately.

The development of Jacob's expertise as a path

Jacob has had a steadily progressing and linear career path in a research field. His study time at TKK was short and concise. Already during the undergraduate studies at ECE, he knew he would continue towards the doctoral degree and further and deeper in his own field. He has worked much in order to promote this in his career.

When the interview took place in September 2008, Jacob estimated that he might be in a kind of post expertise phase. When he has gradually taken over more managerial responsibilities, he has grown apart from his expertise he has gained and has become more a general manager. He can see his expertise in certain phases, and the last three years he has had a general role as managing the others (his employees). However, in spite of this development, he estimates he still has had some expert roles in space projects where he has real expertise rather than being a manager or leader in them.

R: Well, I may be then in this post-expert phase that I am not any more an expert, and I had to, I had a mental struggle in that, it was about expert role, it may been in the end of 1990's when being the leader of laboratory X. Of course, then I was a research professor, but it started to be, however that you did not know about some small details but you had more kind of general knowledge. I was an expert, of course, but not any more in a certain way. And now, of course, the last three years, I could not say that I would be an expert, I know certain facts not in the way experts are expected to know. So now, I am in a kind of, clearly there has been transition phases during the last three years that I do not have an expert role any more, that is behind. But is has been in this way, I have been thinking, in order to act in an expert organisation and keep the touch, so there are certain topics [projects] in which I act as an expert. There are projects in which I have been in, space projects, in which I am more as an expert than a manager. So, with this thought I can keep the touch and then, on the other hand, well, maybe there is just that, you also keep the touch with expertise work.

The future and most important aspects at work

According to Jacob, he regards the growth experience from a young person to a qualified researcher as the most important aspect in his career. This experience has further affected his career and the environment in which he is working. He used the following example:

I: Then we come to the last question - when you think about your whole career what could be the most important aspects in your career?

R: Well, this, I would return to this, this growth experience from a young person to a researcher - so this has been important to me. It is a little bit the same as the child grows there from a small child to an adult. So, there as a researcher you have created these working methods of researcher, and values are, a little, connected to the working methods, maybe your set of values goes that way that you try to do something unique in the world. I do see it so that it has accumulated because the [working] context was good, and I can well see it that it has been a very important growth experience for me and I can clearly notice that it [the research laboratory X at ECE] was a good place to learn.

4.4 Overview of the findings of the narrative stories

This section describes the findings of the interviews. They are divided according to the time span of an expected engineer career: 1) time before starting studies at TKK, 2) higher education studies at TKK, 3) time in working life after graduation, and 4) the future. The interviews were reconstructed as narrative stories following the aforementioned time span. Through the questions, the subjects in the interviews took both backward-oriented as well as forward-oriented perspective to their engineering studies, the substance of them, to their working life at the time of the interview, and a perspective in the future. According to Ropo (2009), the purpose of these narrative stories may be viewed as three-fold dimensions from learning viewpoint. In the first dimension, graduate engineers form their understanding on the engineering curriculum and its substance in relation to their own experiences and life-history. Secondly, they form their conception of themselves, in particular on their professional identity; how they became engineers. In the third dimension, these narrative stories join these people into a community and may join their individual stories into engineering culture. (ibid 2009.)

All these stories are relatively successful; for instance, the respondents in them had had a work through their entire career without any periods of unemployment. The individuals in the stories graduated from ECE, they received work experience, and they have become experts in their own fields. Yet, they had their thoughts and dreams about their future - how to develop themselves in their tasks, and also how to stay still competent in working life. These narrative stories aim to describe their professional growth. I interviewed both female and male graduates, but I did not find any significant differences in perceptions between the perceptions of genders. The single difference was all the male respondents restricted their talk to their work and professional life and did not mention anything about their possible families, or other personal aspects of their life. Two out of the four female respondents

were thinking over their own values when considering their future in the working life and how their family may affect their decisions. Both considered possible changes in their career and job, and had the opinion that instead of more time-consuming task they would prefer a life with a possibility to share adequate time with one's family over a more time-consuming task.

In general, all respondents had been satisfied with their career and work as an engineer. To conclude, their future perspectives seemed to be also rather positive in spite of the pressures they had met in their career, for instance, a constant change in their fields, or a tacit expectation from the employers' side to develop oneself professionally.

4.4.1 The time span before starting studies at university

In the beginning of the interviews I asked each subject to outline the reasons for entering the engineering field and the engineering education. They could start from their childhood continuing to their school times, especially to the time in the upper secondary school. Not surprisingly, all the interviewees told that they had been good, or excellent in mathematics and physics, and very interested in STEM subjects in general. They represented the group of best students in their school classes, and they mentioned that mathematics and physics had always been easy subjects to them. Nearly everyone had chosen TKK as their first and only option when applying to the higher education. A few had also applied to University of Helsinki to study physics, mathematics, or computer science (CS), but they had not regarded this as a serious option. Furthermore, a few of them also had thoroughly assessed pros and cons of different disciplines when they chose which degree programme they would apply to. The following quotation describes this viewpoint:

I: Could you please tell more closely when you got the idea of applying to TKK and engineering?

R: Yes, it was along in the upper secondary school when I thought I might choose medicine [as a field] to be good but I can remember that kind of thing that in some phase I wondered that this engineering is easier – when you blow, then the target [not a human patient] is very silent, but you blow as a [medical] doctor so then the target [a human patient] starts to yell, or at least the members of the family start to yell, either way, so that's how I thought this [engineering] would be a good branch.

Through their narratives it was possible to reconstruct the idea of engineering being a respectable and traditional career choice. With a few exceptions, most subjects had had engineers or architects as role models in their childhood family, for instance a father, mother, grandfather, or an uncle. One subject, Werner noted that *"there was a kind of pressure from home that certain professions are good"*, this representing such values that, in particular academic professions as medical doctors and engineers were the good, respectable and acceptable ones. Many of the subjects in spite of the gender shared the same, deep interest in machines, building and technology in their childhood. This was very often related to the members of family as their role models. These respondents mentioned that they had been constructing, or building something together with a grown-up from the family. Most subjects did not have any pre-conceptions how engineering studies would be, which might have caused some difficulties, or misunderstandings in entering higher education studies.

4.4.2 The higher education studies at TKK

The subjects began their engineering studies at TKK. Rather soon, most of them realised that other students in their degree programme were as good and excellent in mathematics and physics as they were. Sooner or later, however, they adapted the normative style of studies at TKK, for instance, mass lectures for hundreds of students at the same time, voluntary exercises and taking one's own responsibility of studying in general. The subjects found their own learning and study styles. The most common way was to study enough hard according to the way how the majority of the students did – going to the exams, and not attending the lectures, doing the minimum amount of work which was needed in order to pass the courses satisfactorily. In this sense, some differences could be marked in those who had chosen the research-oriented career after graduation. A few of these subjects mentioned that from the very beginning of their studies they had found good friends or study mates. With these friends they started, for instance, to do exercises together and followed the same model schedule in the first years of studies. They stated this helped them to learn more and to complete their engineering studies in a shorter time. In one of the narratives, Thomas made a clear decision of "studying fast and dirty" in the beginning of studies, partly due to his own financial reasons. Another reason was, according his story, that he had always been a sort of "lone wolf". Studying by oneself (not being an active member of the community) was a very common way of at TKK.

However, TKK offered informal activities outside ECE and its formal degree studies. Several subjects had an active free time activity, or acted at the student guilds. In these narratives, studies and the free time activity were closely connected, and this also supported studies and networking at TKK. One interviewee (Lisa) mentioned that she still had very tight connections to the friends she had received at TKK; she had even recently recruited one of them to her current workplace. Nevertheless, one interviewee (Werner) mentioned how he was still bitter of the too one-sided information that he had received from the student organisations at his study time; that the student life at technical universities would be only having fun, and not studying eagerly. Later on, when working at one laboratory at ECE, he could exploit his own experiences when helping younger students with their delayed studies, in particular those who had not completed their mathematics courses during the first years of studies.

It was common to each subject that they were not quite satisfied with the quality of education at ECE. The quality of education had varied depending on the course and the laboratory in responsible. A few professors, one in electromagnetics and one in circuit analysis, were named particularly due to their excellent teaching style and motivation. One interviewee (Benjamin) mentioned that he still used the circuit analysis course hand-out at his work tasks, and recalled this course as one of the greatest at his study time. However, the subjects admitted that their own, further active contribution, for instance, one's own participation as a student, would have affected also their overall learning and quality of the courses.

In their stories the respondents mentioned academic freedom for better or for worse. Academic freedom in these narratives referred to students and their way of studying, not to the traditional concept of academic freedom in teaching. Most respondents had been satisfied with the way of planning their own schedules for studying. However, they also would have required some further support or feedback in general for studying and planning one's studies at a university, or for learning time-management. Some respondents, such as Marie, claimed that the freedom to study with one's own pace gave her a chance to attend a serious free time hobby with competitions and once in a while being absent from the classes. On the other hand, she reflected on the study environment describing it being without any interaction, or giving any sense of belonging to the community.

Through the narratives, it could be noted that the studies at TKK had given them a certain type of engineering framework, or academic engineering

knowledge for use in working life. Competencies which were mentioned, for instance, were logical and critical thinking, problem-solving skills, and information management. The engineering framework which they received enabled learning new competences and skills in working life. Some interviewees in their narrative stories indirectly claimed that the engineering framework or knowledge differed from the one received in studying at universities of applied sciences (*ammattikorkeakoulu* in Finnish). According to the narratives, employers in general appreciated an academic Master's degree in engineering, and this made it easier for the respondents to apply for a job. However, the traditional system at ECE was that students seek their topics for the Master's thesis in the industry, and the instructor of the thesis work may work in the same company as the student's manager. After graduation, all this may have made the applying for the first job more straightforward for the engineering students than, for instance, for the students at University of Helsinki.

4.4.3 The time span in working life

At the time of the interviews, most industry-oriented interviewees worked in tasks not very close to the electrical engineering field. Both industry-oriented and research-oriented interviewees had entered working life either during university studies, or at the latest when completing their Master's thesis. Since that, industry-oriented ones had continued their career either in several, successive companies, or had changed their tasks within a one larger company. Those, who had selected research-oriented career, had worked in different tasks either at TKK, or at a research institute. Five respondents had been working or studying abroad for some period of time in their career. Each one of the subjects had advanced relatively well, and they were also rather content with their work. The typical career path had been as follows: 1) begin as a technical expert, 2) continue as a senior expert, then 3) as a lower manager, and finally 4) proceed in management tasks.

The same type of path could be seen in research positions: first to begin as a researcher, then, after the doctoral thesis, working as a post-doctoral researcher and thereafter, proceeding with further managerial responsibilities. Expertise and professional competencies came along and the respondents increased their knowledge and experience. The higher position the subject had, the less s/he was working with the basic substance of electrical engineering. The interviewees in the highest positions stated they were no longer experts in their primary, original field, but they had taken over the managerial

and general responsibility of their units and lead groups consisting of other experts.

Their perceptions of professional competencies and expertise were much related to their work tasks and to their field. Furthermore, the perceptions mentioned were inter-related. Most subjects had first received a theoretical framework, and then after studies started to grow their own expertise. They expressed in some form that their expertise had mainly grown in various tasks at work. They mentioned that certain competencies learnt at TKK were the foundation for their expertise. These were, for instance, problem-solving skills, logical thinking, critical thinking, and information management. The latest was particularly emphasised because they had evidently faced the fast development of the information society in their career paths. Most of them mentioned that all the new competencies needed in their work tasks they had learnt independently either in work time, or in free time. Participating in further, formal training was barely mentioned. It could be interpreted between the lines that learning new topics was expected to be completed independently, without courses organised or paid by their employers. Information management was also necessary for their learning in order to be sufficiently competent in comparison with the peers in the same field.

In their stories they also referred to competencies that they might need in the future. Furthermore, when I asked about their future, the respondents pondered their satisfaction with their career so far. Despite of their various positions or career orientations, the subjects mentioned that it was necessary to learn additional HR skills and financial management, communication skills, and other languages than English. Some of them reflected their study times, and regretted that they had not sufficiently utilised all the studying options, for instance, taking courses at other departments, or studying other languages than the mandatory Swedish and English courses included in their degree. Overall, they believed that they would need to be continuous learners and to be able to renew their expertise and competencies till their retirement age.

The respondents were satisfied with their career development. Most respondents began their career working in technical support, or in product development, and later on continued in their path toward managerial tasks. They had received sufficiently responsibility, motivating tasks, and increased their expertise in various types of work. However, they mentioned that they had already passed an expert phase in their career, a change that they were not displeased of. When considering other areas of life, merely two female

respondents pondered about their relation between work and family, and, for instance, time management between the two areas. They had solid views about the balance between working life and family; if work tasks were to 'bother' the time for family life in excess, they would prefer work less and keep the balance with the family. As the interview questions posed were rather open, the respondents could have brought forth other areas beside work, such as free time, or their family relations.

It was possible to observe global or national economic trends in their stories. Those who had graduated during the economic boom in the end of 1980's had no difficulties in finding a job. Equally, when studying at TKK, they could easily find summer jobs between the terms. In the beginning of 1990's, a recession began to have effect in Finland. Some respondents, such as Thomas, purposely planned his way how to acquire an employment when there were not many available. He chose to begin in sales tasks as these tasks were not popular among engineering graduates. Most graduates aimed to instigate their career in the research and development field. Another recession period took place during years 2003–2004 which Ada mentioned in her narrative. Those respondents, who mentioned the economic fluctuations, thoroughly assessed them when thinking over their possible career choices. Furthermore, a phenomenon related with this was a change in general. For instance, it could be related to operational environments, organisational structures in working life, or technological development. Benjamin described this well in his story: *"in working life the only definite thing is change but it is not daily, nor monthly nor yearly. You cannot plan much yourself when you work in the industry"*. But, in sum, it was something which respondents could not anticipate. It is likely that global economic trends have a constant effect on students' studies – when choosing one's field of study and during the studies, for instance, when applying for summer jobs. However, the university education with its curriculum design does not have to automatically follow these trends, but to focus on guaranteeing a scientific foundation for the curricula.

It could be stated that the respondents had developed an engineering identity for themselves even though many did not explicitly mention it. Erwin analysed a potential path how a male engineering identity may be formed at TKK, and already earlier during school times. He described a typical male-dominant "engineering path" as follows:

R: If you think about the world of a typical engineer; in upper secondary school large courses in mathematics, in average all boys, who have adopted the

same way of thinking. Then you go into the military service. In my time there were no women at all, nowadays just a few more now. Then you start at ECE with about two hundred and fifty students of which maybe ten are women. Then you end up working at Nokia, well, and then your world view is rather restricted. So, an (or "some") extension of it would be very good for your mental health, but also for your work and career. So, [as an example] it's not easy to work with an Italian-Argentine manufacturer designer with that kind of background.

According to Erwin, electrical engineering education affected forming a type of homogeneous identity for students and graduates. When most respondents felt that it was either not possible to perform interdisciplinary studies, or there was insufficient information about such options, their experiences on studies and courses at other TKK departments or universities were limited. When referring to some perceptions of students' free time (Werner), young students in their first years of study were drifted into taking part in the students' party-culture even though they would not have been so interested in that type of activities. The social pressure of joining others in students' activities may have been too strong for some students. In comparison with the students in other academic fields of study in Finnish universities, these social activities have more powerfully and visibly formed the image of engineering students and their social culture (*teekkarikulttuuri* in Finnish). In some sense, this has supported the incorrect usage of the term 'academic freedom' – from students' viewpoint the meaning includes a notion to decide about one's own time-management during the studies without a severe responsibility to complete one's studies in the predicted time.

In the summary (Chapter 5), the results of the entire study will be combined. The results of the narrative stories raised many phenomena which were found in the previous research. From the point of view of the curriculum design in engineering education, there are still many significant topics to be studied in this field. In Chapter 6 (Conclusions), the relevance of the results will be discussed from different viewpoints, and ideas for the future research will be elaborated.

5 Summary of the results

It is essential that engineering curricula at universities support the development of students' expertise and competencies in working life. Furthermore, it is also significant the types of engineers universities are 'producing' for the industry and labour markets. Graduated engineers are not experts when entering working life, but the education should provide the elements to enable them to become experts when combining the accrued substance into the various tasks given at work. Engineering education will offer the necessary foundation in engineering theory and practice. The aim has been to gain insight into engineering education, particularly in electrical engineering, as well as the perceptions which engineers in working life had on their studies. Furthermore, the study examined the perceptions of expertise and professional competencies experienced by electrical engineers in their studies. This summary forms a conclusion of both quantitative and qualitative results documented in Chapter 4. The results are presented and analysed according to the three research questions (see Chapter 3.1.) However, as the data samples are not large, the results in general may be indicative and applied in engineering education development.

Engineering education in Finland has had common functions and features in the last few decades. The technical universities have, for instance, had a common, nationwide entrance examination system. The examination system has been based on the national matriculation examination results and the core curricula taught in mathematics, physics and chemistry in the upper secondary schools (*lukio* in Finnish). The Finnish National Board of Education decides on the core curricula in the upper secondary school level. (The Finnish National Board of Education 2012.) Thus, Finnish students applying to technical universities have principally received a coherent and equivalent level of education in sciences regardless of from which part of the country they originate.

The electrical engineers and students in electrical engineering have followed the same basic structure in the studies as all engineering students at the former TKK. Sciences, such as mathematics, physics, information technology and chemistry (STEM fields) are taught during the first three years of studies. After this phase, students move on to a more substance-based deeper level of learning in various engineering fields, and continue their study path at the Master's level. It is not uncommon that students have taken a part-time job after the first two or three years of further intensive studies. Moreover,

most engineering students have completed their Master's thesis for a company or "in the industry" as termed among the professors, teachers, and students at former TKK. Quite often they have been able to continue their career at the same company after having completed the Master's degree at the university.

The challenge in completing this chapter was in writing and analysing the data gathered according to each approach and methodology. The different styles of language and terms were used according to the methodological traditions, in documenting findings or results either collected with quantitative or qualitative research. In this chapter, as the research field is primarily interdisciplinary, an attempt has been made to cross boundaries of various research areas. (cf. Berry 2006; Kincheloe and Tobin 2006.)

5.1 How did electrical engineers describe their studies at TKK?

The first research question can be answered in different ways depending on the methods by which the data were collected and analysed. Both quantitative and qualitative results of the research will answer to this question. The quantitative data from surveys provided numerical answers, for instance, such as the percentage of the respondents satisfied with their studies at TKK. In turn, with the qualitative data collected, the perceptions the interview respondents in the narratives had, were interpreted.

In general, the results of the surveys and narrative stories showed that electrical engineers graduated from ECE had been basically content with their studies. According to the narrative stories and the qualitative data from the second survey, the respondents believed they had received a good general engineering knowledge, or a basic foundation in electrical engineering at ECE. However, the findings of the narrative stories showed that the interviewees had also received somewhat negative experiences during their studies. These experiences were related to the learning and teaching processes. They mentioned a lack of interaction in the teaching, or not sufficient contact with the professors and teachers which would have helped their integration into the community. Furthermore, the relation between the theory and practice should have been clearer, particularly in the beginning of the studies. Some of the respondents described their experiences by suggesting that they could have passed their studies through sufficiently strong calculating skills alone, and being mute and illiterate would have made little difference.

Mathematics courses in the beginning of the studies were mentioned to be too theoretical and difficult. Furthermore, the teaching methods in the mass courses in mathematics were regarded inadequate. Many respondents mentioned the large differences between the substance taught at upper secondary school and university. Partly due to the large number of students per class (possibly often many hundreds of students), and the teaching methods, respondents had not been able to follow the teaching nor sufficiently comprehend the substance of the courses. Furthermore, the focus of the teaching should have been further in engineering mathematics, and not merely in pure mathematics. Moreover, the link between mathematics and the substance of electrical engineering courses should have been clearer. Mathematics and physics belong to the classical professional curriculum in engineering. Thus, engineering curriculum during the first years of studies has mainly focused on these substances. In several working groups at former TKK there has been debate and also criticism of the relation between the theoretical and more applied subjects, and the role of mathematics in the engineering curriculum.

The respondents had either been told by teachers or older students, or they had realised themselves that the elements guaranteeing success in upper secondary school studies in mathematics were not the same in higher education. Questions about the learning approaches were not directly asked (Bowden and Marton 1998; Entwistle 1997) either in the surveys or interviews, but my interpretation of the narrative stories is that the education during the first years at ECE did not itself support the development of the deep approach in learning. Most respondents' learning style seemed to remain on the surface level. Moreover, most of them mentioned that they could not memorise the substance taught in mathematics after their studies. However, during the first years of studies, some of them had established their own study peer groups with other students. Co-working had supported their learning, fluency in studies, and their integration into the community. The results indicated that education in the later studies was more applied, and given in smaller groups which had been a positive experience. According to the respondents, this supported their learning and overall comprehension better. It possibly supported adopting the deep approach learning style as well.

Many interview respondents had mixed feelings of not being 'the best student in the class' any more. In extreme cases, some of them had feelings of being depressed, because they had not comprehended the taught substance. Even so, many of the interviewees stated that they themselves could have taken a more active role as a student. These perceptions and experiences are partly related to becoming or being a member in the community of practice

(Wenger 1998; Wenger and Snyder 2000). If the students stayed on the outer circles in the community, it may have had negative effects on their integration and motivation. Thus, they probably would have remained more passive learners during their time of studies.

One of the results in the second survey showed that engineering students with delayed studies had had motivational problems due to various reasons. Some reasons, such as economic, may not have been easily helped with the guidance given at TKK. However, delays caused by motivational and time management difficulties, should be helped with support by different guidance functions at the university. Nevertheless, the respondents in the second survey felt an overall satisfaction in the study guidance services, and a part of them believed they had not needed guidance at all. However, it has been noted that students may not have found the study guidance services, and the information and knowledge given may be either too complicated to find, or too hidden in the webpages of the university.

The engineering culture (Godfrey 2009; Godfrey and Parker 2010) plays a significant role in the community of learning at a university. The engineering culture at one community, in this case a university, consists of both its formal (education given by the faculty) and informal parts (for instance student guilds and other informal bodies). When a student becomes a part of the community (in this context Aalto School of Electrical Engineering), s/he regards it from various viewpoints. The narrative stories supported the importance of integrating students to the community from the very beginning of their studies. However, the experiences of the respondents of joining the community had not been all positive. In upper secondary school, most of them had been the most successful students in sciences. However, when starting studies, they had been told they might not be the best ones any more, and they gradually accepted the idea of not receiving as good scores as they once had. This was particularly mentioned in their experiences in mathematics studies. Partly, a more intensive integration into the university studies could have better supported their motivation for learning, and not merely 'performing studies' as some respondents mentioned. During the first years of their studies, they somehow solved the contradiction between their own perceptions of their skills. Furthermore, they adopted new learning skills in order to manage with academic studies and at the community in general.

The respondents in the interviews pondered their relation and role to the studies and other students as well. Erwin described that when he started his studies he noticed that there were other students who "were born engineers".

Quite soon he himself had noticed he was cut from a different cloth. Marie mentioned she did not choose such subjects (radio science and technology, electronics) to which the majority of students had "a deep passion", but she preferred to select a more general approach in her own study path. According to the narratives, the academic student culture at TKK did not always support the image of a serious student who, amongst other typical student activities, eagerly participates in lectures and exercises, reads for weeks for the exams. On the contrary, engineering student party-culture was annually transferred to the generations to come. Also, the tacit knowledge that students did not have to participate in the lectures was quickly transferred to new first year students. However, these respondents who had taken lectures had received somewhat negative experiences – the lectures had not involved sufficient interaction between the teachers and the students, or teachers did not sufficiently motivate students. For instance, they did not link the substance to other courses in their degree, or the quality of the studies was mainly dependent on the attitude of each teacher or professor. Still, many interviewees had experienced the informal and social side of the engineering community in a positive way – they participated actively in guild and other free time activities, and later on in working life, shared the same networks and people with whom they were affiliated at TKK. As a whole, the engineering culture could consist of a balanced sum of different sub-parts of different cultures – responsibility to one's studies and having fun at the same time.

Various elements affect the creation of engineering education culture. The predominant culture has either a direct or indirect influence on the curriculum design and studies, and there are many parts in the 'cultural' system. To mention some, there are teaching personnel with different positions of employment (professors, teachers, researchers, and assistants) and their teaching styles, students with their different backgrounds and orientations in studying, and employers who recruit becoming engineers. One of the targets in the engineering learning community is to be able to create an **"engineering way of thinking"** for the students**.** Depending on each student, this should be a composite produced by the aforementioned factors. The prevailing engineering education culture should support this process. Should some parts lack, or they be inadequately planned in the community, the outcome may not be what was expected. Therefore, hidden or tacit aspects affecting the learning should be better recognised and considered in the engineering curriculum design process.

5.2 How do electrical engineers perceive expertise and professional competencies?

The results, in particular in the narrative stories, showed that expertise and competencies were mainly learnt in working life, although the Master's degree in electrical engineering had given general engineering knowledge, knowledge in the selected domain, and a scientific foundation for a professional career in engineering. Likewise, these narratives also maintained theories that expertise grows gradually when working, using and combining the substance and knowledge received in the education. Thus, it means that electrical engineers when graduating from the university are *not* complete or qualified experts, but have merely received the foundation for the development towards expertise. In general, the respondents in the second survey and in the interviews had the same type of perceptions of expertise and professional competencies.

In the study, all interviewees excluding one had more than 10 years of work experience. Each in their own way defined their progression in becoming experts in their career. Likewise, some even claimed that they had moved into *a post-expert phase* once they had begun to lead teams of other experts, or expert organisations. Their experiences in growing gradually as experts and reaching the next phases or levels supported prior theories on expertise, for instance by Bereiter and Scardamalia (1993), as well as Dreyfus and Dreyfus (1986).

The respondents in the narrative stories mainly based their perceptions of expertise around **knowledge** – constructing their knowledge, to be able to analyse, structure, share, or tell about it. Werner described it with the expression "refining one's own expertise". Some respondents compared experts to teachers, or persons helping others with their own expertise. Furthermore, it was described as knowing well one's own limits and restrictions. One respondent, Marie, defined her expertise very representationally as *'a grocery store'*; she told as her expertise was rather wide covering a large area with an ability to solve various problems. Referring to the respondents' perceptions of expertise and being an expert, the respondents stressed correspondingly the ability to solve problems. Depending on the work context of each respondent, s/he saw problem-solving either through people, or substance. Thomas, who had mostly worked in various sales tasks, emphasised the relation to clients (either internal or external) in defining expertise and problem-solving. He expressed the competence to adjust one's expertise to a client's situation. The notions of hard-pure discipline arose with one respondent; Benjamin related

his perception of expertise on measuring and calculating a problem, and documenting the results rigorously to the others, for instance, to colleagues, or clients. He added that incorrectly measured and calculated engineering problems do not have their place in his perception of expertise. Three respondents (Erwin, Simon, and Jacob) linked their views on expertise with growth; becoming an expert had been "a good opportunity for growth", or working as a member of a research team had been "a growth experience". Overall, these results supported the thoughts by Reich (1993) that engineering is among the knowledge-intensive professions.

The second survey included an assessment on professional competencies and where the respondents had learnt them. The five most important competencies according to the respondents were the following: **problem-solving skills, knowledge of own field, information management, systemic thinking, and critical thinking**. These results are also consistent with the prior research. For instance, the US study by Davis et al. (2006) on engineering profiles emphasised the meaning of being able to analyse and solve problems. Furthermore, Scott and Yates (2002) in their study among graduates from Australian universities emphasised competencies in analysing and resolving real-world problems. In the prior study by Martin et al. (2004), this was described as 'technical competence' and the 'ability to solve problems', and found also substantial. The most appreciated competencies in these results could also be divided into key technical and non-technical ones.

One of the tacit targets in curriculum design is to integrate non-technical skills and competencies into the education. When designing the theoretical substance of each electrical engineering subject into the curriculum, it is equally pivotal to incorporate non-technical skills and general academic skills. These are, for instance, knowledge management, communication skills, group working skills, and learning to learn skills. Both the qualitative results of the students with delayed studies, and the narrative stories supported this finding. This is partly consistent with prior research, for instance, by Korte, Sheppard and Jordan (2008), Martin el al. (2004), Tynjälä et al. (2006), and the OECD DeSeCo-results (Rychen and Salgarnik 2003) in which the social context of the work, social nature of work, and communication skills (for instance communication in the workplace) were found significant.

The respondents of the second survey had not learnt these skills sufficiently at TKK. They had mainly adopted them in working life, either because of their employer had required, or they were presumed to administer certain competencies when they had moved, for instance, to a new job. In practice, they had

self-studied new skills in their free-time; for instance, reading manuals, or other types of literature. Very seldom they mentioned having been to a course or training on some topic. The results supported the idea that **learning** and **learning to learn** is an essential part in engineering expertise. The respondents in the second-survey qualitative answers stated that engineering expertise is continuous self-development, or learning, or it means *"tasks which demand learning new"*, or *"engineering expertise at its best is diverse learning, developing and knowledge in a dynamic work environment."*

The other part of the question, how the respondents in the second survey assessed where they had learnt professional competencies, was more challenging to evaluate. The typical answer in the survey was that they had learnt the competence of learning both at work and at university. The highest shares were both with information management and knowledge of own field; 56% had learnt them both at work and at university. Regarding the curriculum design in engineering education, the integration of professional competencies, such as learning to learn, should be even further emphasised. Likewise, knowledge transfer from theory into practice could be underlined. This may also signify that the curriculum at technical universities should consist of more links to the working life and other stakeholder groups. Even though teaching personnel at a technical university do have connections between the companies and the industry, it should be more systematically operated in all substances. Accordingly, teaching personnel possess a fundamental role in the curriculum design in creating and maintaining their networks with the industry and other stakeholders.

According to the respondents of the narrative stories, certain skills or competencies were lacking from their studies (see Figure 22). These competencies may form, or give a picture of 'generalist' engineer working in system-analytic tasks without a notion of any specific engineering discipline. This can be compared to Reich's (1993) division of the future jobs in which people working in system-analytic tasks have received a broad work field. Different disciplines, electrical engineering among many others, form a larger image of the work. This is particularly pivotal when leading a group of experts in whose field different engineering disciplines are included. On the whole, these 'general' types of competencies are equal for all experts and support the development in system-analytic tasks.

- Leadership and management, particularly in HR area
- Business knowledge
- Financial knowledge
- Foreign languages (in addition to English)
- Budgeting
- Contractual law
- Entrepreneurship (e.g. establishment of one's own company)
- Oral and written communication skills

Figure 22. *The professional competencies lacking from the studies of the narrative stories' respondents (author's original diagram)*

The respondents described and listed these competencies and skills within incidents happened during their career. The typical way was to describe a transition phase; how they had received new tasks and noticed themselves that they should acquire some new competencies, or refresh such which they had partly adopted earlier. Most respondents shared the perception that graduated engineers should manage basic knowledge on marketing, budgeting and management skills. Werner defined this well stating that *"I have so much experience in working life myself so all those years when I worked in company X [in ICT field], every single boss had to do his/her own budgets, and today bosses increasingly have to assume more diversified responsibilities."* When writing this summary some years after I collected the interviews, I could presume that most engineers increasingly face this demand in their work career.

5.3 How do electrical engineers describe their engineering career?

The data for the third research question has been mainly obtained from the narrative stories and the perceptions of the respondents. Their answers to the research question originate from the time before the respondents had started their engineering studies at TKK. The seeds or origins of their career were initially planted in their childhood and teenage times. Most respondents in the narrative stories had some sort of role models of engineers in their family. They had been talented in mathematics and physics at school. At the latest in upper secondary school, most of them had sketched their future in engineering studies. There was merely the question of choosing between different engineering disciplines. They might have pondered some others options at TKK, such as industrial management which has been and still is one of the most

"popular" degree programmes to apply. However, even if they had applied to various options, they did not actually take them seriously but chose to study electrical engineering. Some respondents mentioned that their families had given them an impression that they should seek for "a respectable profession" or "a good profession". Engineers graduated from TKK have traditionally been regarded as such. Impressions of a 'respectable' profession could base on assumptions that during the past decades engineers graduated from TKK have received well-salaried jobs with good career prospects.

The narrative stories in spite of their individual differences can be noted to follow a larger schema. In the childhood the respondent had an engineer in the family as a role model. In school s/he was very keen on sciences, and could perform them very well, typically this person was the best one in the STEM subjects. During the time in the upper secondary school s/he already had received the idea of applying to TKK. It was easy to pass the entrance exams and to become an engineering student. But the first year of study was as if s/he had come into a new world with an academic studying culture. The respondent had to learn to take responsibility of one's own time and studies. In an average "story" it went fine. S/he could manage the studies, but was not one of the most brilliant students but did not either try to be such. In the end of studies, s/he received an interesting Master's thesis topic and began to work for the "industry". Before that, s/he was already working during summer holidays and sometimes during the terms with different companies. The respondent completed the Master's thesis, and continued working in the research and development tasks for the same employer. After some ten years, s/he received more responsibilities and tasks, and started leading a team of other experts. Then s/he noticed that the advanced knowledge about HR management, budgeting, or marketing became very important. He could study some formal courses on these areas but learnt about these topics also in his/her free time. After some 15–20 years in working life, the person had become a general manager at a larger globally-owned company, and was focusing on staying competent at work until his/her retirement age.

The findings of the narrative stories supported the idea that the respondents in general were satisfied with their engineering career. They had followed either a science and research-oriented, or an industry-oriented career path. First of all, there were no significant differences in the satisfaction between these two groups. There were many respondents in the industry-oriented path, who had worked in research tasks either at TKK, or at a research institute. However, after some years of work experience, they had changed into an industry or company-oriented path when they had noticed

they would not prefer becoming an academic researcher. They had faced a transition phase during which they had analysed their own career and targets, and had decided to change to another path.

The respondents had worked as experts in their own fields, and when getting gradually work experience, responsibilities and knowledge, their work had changed from a certain area of expertise into a wider field. Therefore, many of them had become managers or leaders who were in charge of units of experts. Most interviewees had already become **generalists** working with the actual substance, electrical engineering, no more. This could be compared with the prior studies from Sweden by Nilsson (2007) and Axelsson (2008). There were certain roles, or types of engineers found in the stories. The most common were either **a research and development (R&D) type**, or **a designer**. Respondents belonging to this type had started their career in more basic kind of R&D tasks, and gradually proceeded further in the system. Their main tasks had been in the research and development area but most of them described that due to their career development they had learnt, for instance, budgeting, marketing, contractual law, or management in working life.

Another common type of career path among these engineers was **a general manager**. These people had first worked in R&D oriented tasks, but gradually took over more responsibilities, for instance, leading a group of other experts. They mentioned that they had sought more knowledge and training in competence areas related to management and business. Furthermore, quite a few mentioned that in management and leadership tasks one can never learn sufficiently – there is always more to study. One role which was not common but found in Thomas's story was **a sales person**. It had been his deliberate plan to follow this track mostly due to the labour market situation in the 1990's. He mentioned that it was among the most unpopular career paths at that time.

The ones, who had chosen a scientific-oriented career, could be divided into two main types: pure **researchers**, and **teaching-oriented researchers**. The latter group were in research but had also been teaching at their departments. Teaching had given much content and satisfaction for them and supplemented their knowledge and experience in the domain they had taught. For instance, Simon, one of the scientific-oriented respondents, mentioned teaching to be one of the most important aspects in his career. Furthermore, it was stated that teaching and research work have supported well each other, and could not be separated from each other. Likewise, Ada mentioned that

during the courses, students had offered her new viewpoints, particularly for her research work.

The last part of the narratives described how the respondents regarded their career in the future. They had positive visions about their own future in working life in general. They shared the perception that through their independent learning they should stay competent and constantly update their competencies and skills. However, they did not have unrealistic or rosy views on working life. According the narratives, change or unpredictability was in general a part of everyday working life. Even though the respondents had been satisfied with their career so far and they had been able to learn all those new competences and skills they were expected, they noted that change or unpredictability were constant factors affecting their career. Most respondents with industry-oriented career had got accustomed to the pressure of learning new facts quickly when required, sometimes without pre-knowledge of the topic. An example of this was an analogy of a person not able to swim but who is pushed to the water from a pier and being told to learn with a manual.

Other phenomena that have risen up from the narratives were globalisation and economic trends in a larger scale. Globalisation affected the careers of the industry-oriented respondents. Many respondents worked for international companies which functioned globally in many countries and continents, and whose industrial plants had partly been moved into lower-cost countries, for instance, to Asia. Furthermore, some respondents described their working teams to be global and inter-cultural environment and communication was a natural part of their work.

Overall, the respondents in the narratives were used to the thought that the circumstances were constantly fluctuating, and they themselves had to stay sufficiently competent and flexible in order to manage well in working life. However, due to their engineering knowledge and competencies they had received a certain kind of confidence to the future and were not pessimistic about their prospects. Gustav, one of the industry-oriented respondents, captured quite well this idea stating in his story that he was “not a drifting wood” but he wanted “to paddle to his own direction”. It could be interpreted that the electrical engineering education received at ECE could provide these respondents a certain kind of positive expectation, or a belief to be able to manage in their career and future.

6 Conclusions

In this chapter I will draw conclusions on the study from different angles: from theoretical, methodological, and practical viewpoints. Furthermore, I will outline the limitations of the study, and give suggestions for the further research on this field.

From the theoretical viewpoint, the results in general supported prior research on expertise and professional competencies. In the context of electrical engineering, students receive the seeds for growing as experts and gaining professional competencies. Later in working life, by their own initiative or with the support of the employer they recognise potential needs for their professional development and accrue knowledge or actual training in the required areas. But most of all, the respondents in the narratives and in this research were flexible experts with a wider perspective. The present development in technology and engineering requires the need for wider expertise with an ability to learn more, and to identify one's own learning capacity and competence in learning. Furthermore, in regard to the curriculum development, this study may offer some thoughts about the significance of engineering career paths for the university and the society. For instance, from the economic viewpoint, the majority of the engineers graduated from technical universities begin to work in the industry and companies in the private sector. Thereby, it is extremely significant to educate qualified persons who have received a good foundation to grow as an expert. Referring to the societal task in Aalto University's strategy, this as a whole signifies that the engineering education provided for the students serves the Finnish society as well as the global one.

Methodologically, the results supported an approach that uses mixed methods combining quantitative and qualitative methods and data collection. Quantitative methods have their particular and justified place in the methodological field but qualitative research in engineering education is essential as well. Numbers in the form of frequencies, or more developed forms as a cluster or regression analysis often offer answers to the research questions. Nevertheless, an in-depth interview study can still provide enhanced knowledge, for instance, on the perceptions of studying. In this research, I used the qualitative, in particular narrative approach, which for the present is not much applied in engineering education research (EER). It was very interesting, challenging, and rewarding for a researcher. This approach could be recommended to be applied increasingly in this particular field.

From the practical point of view, this research was a sort of pioneer study in electrical engineering education. I have already been able to exploit the results in the pedagogical development at Aalto ELEC, particularly in the on-going curriculum renewal process. The process continues during the next years, when new Master's programmes in electrical engineering will be designed. Their implementation will take place in 2016. In Aalto University, all the studies completed in this field offer essential knowledge for the development work in general, and for the different stakeholders at various levels. It may be pointed out that the curriculum development in engineering should be more systematically and pedagogically managed than at the moment. Furthermore, co-operation and knowledge sharing in education development between different actors (such as different departments and study administration) should be increased. The common goal for the development should be a well-planned and flexible study path in engineering providing foundation for knowledge and expertise in the chosen area. Moreover, another aim should also be engineering education which will provide professional competencies in a constantly changing global working life. A practical result may have been to construct a new model for electrical engineering education. But, as Aalto University commenced the curriculum reform at four engineering Schools in 2011, it was more worthwhile to attempt to influence the on-going design process. In practice, I was able to apply these results at Aalto Bachelor renewal committee as a representative of Aalto ELEC. Later on, I will continue working with the co-ordination of Master's programme design at ELEC.

At this point, it is appropriate to evaluate the qualitative results of the study. Due to many reasons such as time difference, or individual experiences, the persons in the narratives could express their perceptions of the education they had received. Their re-collections of the time 15–20 years ago might not completely correspond to the reality according to the expression 'memories grow sweeter with time'. However, when most respondents shared similar perceptions, the results as a whole are important.

This research has been among the first in the EER field at TKK. Kinnunen (2009), Korhonen-Yrjänheikki (2011), and Leppävirta (2011) completed their theses in this area recently. Furthermore, during this process I have been able to participate in the European EER network with research colleagues at SEFI (European Society for Engineering Education) to promote the new field. The disciplinary definition of the EER field has been one of the challenges when completing this work. In the beginning of the study, my own identity as a researcher was closer to the educational sciences. As I proceeded on with the

work, I have become more acquainted with the engineering field and "the engineering way of thinking".

With this work I suggest that it is essential for engineering education to receive further research data and results gathered by the teaching personnel at the universities. Higher engineering education itself differs not much between the disciplines, but the substance taught in various engineering fields can make a difference. The overall quality of education in electrical engineering, or other disciplines which consist of theoretical substance, challenges instructors. It concerns all sizes of courses, but particurlarly the mass courses in the beginning of the studies. New research data in engineering fields could benefit both those who teach and those who design the curriculum. Furthermore, engineering education should be founded on researched-based data how students learn. Prior research in Finnish engineering education has not yet been conclusive. In US, The Engineering Education Research Colloquies (EERC) has defined research areas for the EER field. They include, for instance, engineering learning mechanisms, assessment, and learning systems. (The Engineering Education Research Colloquies 2006, 259-260.) The research areas suggested by EERC could also well promote the EER field in Finland.

There are limitations to this study. My background as having worked at ECE probably affected simultaneously negatively and positively. I had worked as a teacher at ECE, and gradually acquired knowledge about the engineering education as a discipline. Should I have arrived as a complete 'outsider' from the world of educational sciences; I contend I could not have managed to complete the narrative part of the study. My research experience brought some limitations. I had prior experience in qualitative study projects, mainly with interviews. Thus, I should have examined the quantitative research approach in more detail. If I could re-design the quantitative surveys, I would probably complete them differently.

Furthermore, another limitation was not being a part of a larger research group. Quite often it was rather lonely to proceed in the work, but I could have very fruitful discussions with my supervisor and in particular with my instructor. But I mainly had a discourse with myself. When I completed two refereed articles in co-operation with Miia Martinsuo, and Henrik Wallén, it was one of the most rewarding and useful experiences during this work. In this point, I could borrow an extract from one of the respondents in the narratives: the academic world has changed during the last few decades; academic researchers have to learn to write joint articles, and in general, coworking with other researchers forms an essential part of academic work.

The results support the prior research in the EER field. They provide evidence for further curriculum design in electrical engineering at the national level. Moreover, they would seem to suggest that learning the basis of expertise and professional competencies should be particularly well integrated into the education. The results show that both successful higher engineering education, and experience received in working life are essential to develop an expert in the engineering field. The research focused on electrical engineering. Nevertheless, comparative research within other engineering disciplines is essential, for instance, completed at other technical Aalto Schools. Expanding the quantitative studies on learning, expertise and professional competencies, would dispense valuable support for the university level pedagogical development. Moreover, qualitative research focusing on academic teaching personnel (professors, lectors, and teachers) could provide knowledge for the enhanced pedagogical development. The ground at Aalto may be fertile due to the on-going curriculum renewal process.

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Appendices

Appendix 1. The invitation letter for the first survey
Included in e-mails asking for the participation in the first survey, sent in Finnish

Hei Sähköosaston alumni!

Apuasi kaivattaisiin nyt. Anna palautetta Sähköosaston opinnoista ja edistä osaltasi TKK:n opetuksen kehitystä.

Alta löydät tarkemmat tiedot tutkija Kirsti Keltikankaan tutkimuksesta sekä linkin itse kyselylomakkeeseen.

Parhain terveisin,
Nora Rahnasto
PoliAlumni

Hyvä sähkö-DI ja PoliAlumnin jäsen,

Tämän kyselyn avulla pyritään selvittämään TKK:n sähkö- ja tietoliikenneosaston opetuksen tieteellis-ammatillista tasoa, erityisesti kenttäteorian kurssien osalta. Kysely on osa laajempaa tutkimusta, jota teen sähkö- ja tietoliikenneosastolla. Saatujen tietojen avulla pyritään kehittämään sähkö- ja tietoliikennealan perusopetusta sekä jatko- ja täydennyskoulutusta. Sinun mielipiteesi sähkö- ja tietoliikenneosastolta valmistuneena DI:nä ovat erittäin arvokkaita!

Vastaa kysymyksiin valitsemalla omaa käsitystäsi parhaiten kuvaava vaihtoehto. Jos kohdassa saa valita useamman vastausvaihtoehdon, siitä on ilmoitettu erikseen. Joihinkin kysymyksiin voit itse kirjoittaa vastauksesi. Jos mietit, että perusopinnoistasi on kulunut aikaa etkä ehkä muista niihin liittyviä yksityiskohtia, koeta silti vastata! Pyydän, että vastaat jokaiseen kohtaan.

Kyselyn tulokset käsitellään luottamuksellisesti, ja niistä tehdään koko opiskelijaryhmää koskevia päätelmiä. Yksittäisen vastaajan tiedot eivät käy aineiston päätelmissä mitenkään ilmi. Jos olet kiinnostunut osallistumaan tämän kyselyn jälkeen tehtävään haastatteluun talven 2007 aikana, kirjoita sähköpostiosoitteesi lomakkeessa viimeisenä olevaan kenttään.

Pyydän sinua ystävällisesti vastaamaan kyselylomakkeeseen mahdollisimman pian, kuitenkin **viimeistään perjantaina 1.12.2006. Vastaamiseen kuluu noin 10–15 min aikaa.** Paljon kiitoksia etukäteen vastauksistasi!!

Kyselyyn pääset tästä linkistä: http://www.dipoli.tkk.fi/ok/php/form.php?form=opetuksentasosahko06

Jos haluat lisätietoa kyselystä tai koko tutkimuksesta, ota yhteyttä!

Ystävällisin terveisin, Kirsti Keltikangas
Tutkija, sähkömagnetiikan laboratorio
09-451 4906/ 040 xxx xxxx
kirsti.keltikangas@tkk.fi

**** TKK:N ALUMNITOIMINNASTA

Lisätietoa TKK:n alumniverkostosta voit lukea www-sivulta: https://polialumni.tkk.fi/

Jos sinulla on kysyttävää, otathan yhteyttä TKK:n Alumniyksikköön, palvelupäällikkö Nora Rahnasto: alumni@tkk.fi, puh. +358-(0)9-451 4675

Appendix 2. The first quantitative survey (in Finnish)

Kysely TKK:n sähkö- ja tietoliikenneosaston opetuksen tieteellis-ammatillisesta tasosta

Tämän kyselyn avulla pyritään selvittämään TKK:n sähkö- ja tietoliikenneosaston opetuksen tieteellis-ammatillista tasoa, erityisesti kenttäteorian kurssien osalta. Kysely on osa sähkö- ja tietoliikenneosastolla tehtävää laajempaa tutkimusta. Saatujen tietojen avulla pyritään kehittämään sähkö- ja tietoliikennealan perusopetusta sekä jatko- ja täydennyskoulutusta

*pakolliset kentät

Taustamuuttujat

*1. Olen

- Nainen
- Mies

*2. Syntymävuoteni (vvvv)

*3. Asuinpaikkani

- pääkaupunkiseutu (Helsinki, Espoo, Vantaa, Kauniainen)
- muu Uudenmaan kunta
- muu kuin Uusimaa

*4. Peruskoulutukseni on

- yliopistotutkinto
- ammattikorkeakoulu
- opistotasoinen tutkinto
- lukio
- ammattikoulu tai muu perusaste

*5. Työkokemukseni valmistumisen jälkeen

- 1-5 vuotta
- 6-9 vuotta
- 10-14 vuotta
- 15-20 vuotta
- yli 20 vuotta

*6. Olen valmistunut TKK:n sähkö- ja tietoliikenneosastoltavuonna

pääaineeni

*7. Olen jatko-opiskelijana

- en suorita tekniikan alan jatko-opintoja
- jossain muussa korkeakoulussa kuin TKK:lla
- jollain toisella TKK:n osastolla
- TKK:n sähkö- ja tietoliikennetekniikan osastolla,

tutkimusalani (pääaine)

*8. Suoritan tekniikan alan jatko-opintojani

- en suorita tekniikan alan jatko-opintoja
- päätoimisesti (tutkijakoulu, apuraha, työpaikka TKK:n laboratoriossa ym. vastaava)
- sivutoimisesti päätyöni ohessa

Opinnot Teknillisessä korkeakoulussa

Tässä osassa pyritään selvittämään millaisiksi olet kokenut opinnot TKK:n Sähkö- ja tietoliikennetekniikan osastolla, erityisesti kenttäteorian kurssien osalta.

*9. Miten kiinnostunut olin matemaattis-luonnontieteellisistä aineista aloittaessani
opinnot TKK:lla

- erittäin kiinnostunut
- melko kiinnostunut
- en osaa sanoa
- melko vähän kiinnostunut
- erittäin vähän kiinnostunut

*10. Miten kiinnostunut olin sähkö- ja tietoliikennetekniikan opinnoista opiskellessani
TKK:lla

- erittäin kiinnostunut
- melko kiinnostunut

- en osaa sanoa
- melko vähän kiinnostunut
- erittäin vähän kiinnostunut

*11. Mielestäni sähkö- ja tietoliikennetekniikkaa opetettiin TKK:lla

- erittäin hyvin
- melko hyvin
- ei hyvin eikä huonosti
- melko huonosti
- erittäin huonosti

*12. Sain ohjausta sähkö- ja tietoliikennetekniikan osaston opintoihini tarvittaessa

- aina
- yleensä
- useimmiten
- harvoin
- en koskaan
- en kokenut ohjausta tarpeelliseksi

13. Mikäli sain ohjausta sähkö- ja tietoliikennetekniikan opintoihini, niin keneltä/miltä
taholta

- ☐ muilta opiskelijoilta
- ☐ isohenkilöiltä
- ☐ opintoneuvojalta
- ☐ opintosuunnittelijalta
- ☐ professoreilta tai muulta opetushenkilökunnalta
- ☐ muualta, mistä?

Seuraavat kysymykset koskevat sinua mikäli kenttäteorian kurssit (S-96.111/S-96.121/S-96.101) kuuluvat tai ovat kuuluneet opintokokonaisuuteesi

14. Läpäisin staattisen kenttäteorian kurssin tentin [ ] tenttikerralla

15. Läpäisin dynaamisen kenttäteorian kurssin tentin [ ] tenttikerralla

16. Läpäisin sovelletun kenttäteorian kurssin tentin [ ] tenttikerralla

17. Opintojaksot

- [ ] En ole vielä suorittanut staattisen ja dynaamisen kenttäteorian (tai sovelletun kenttäteorian) opintojaksoja

*18. Kävin kenttäteorian kurssien luennoilla ja laskareissa

- aina
- yleensä
- usein
- harvemmin
- en koskaan

*19. Kenttäteorian kurssit olivat mielestäni työmäärältään

- erittäin helppoja
- melko helppoja
- ei helppoja eikä vaativia
- melko vaativia
- erittäin vaativia

*20. Kenttäteorian kurssien työmäärä oli mielestäni sopiva saatuihin opintoviikkoihin/opintopisteisiin nähden

- täysin samaa mieltä
- samaa mieltä
- eri mieltä
- täysin eri mieltä

21. Olisin tarvinnut apua seuraaviin asioihin opiskellessani kenttäteorian kursseja

- [ ] luentojen sisältöjen ja teorian oppimiseen
- [ ] laskuharjoituksiin

- [ ] kotitehtäviin
- [ ] ryhmätöihin
- [ ] Matlabin tai jonkin muun kurssilla tarvittavan tietokoneohjelman käyttöön
- [ ] muuhun, mihin?

22. Kenttäteorian kurssit olivat mielestäni

*a. laajuus
- liian laajoja
- sopivia
- liian suppeita

*b. vaikeus
- liian vaikeita
- sopivia
- liian helppoja

*c. selkeys
- kurssin alkaessa minulle selviä
- epäselviä, miksi?

*23. Miten kenttäteorian opinnot liittyivät muihin sähkö- ja tietoliikennetekniikan osaston opintoihini

- erittäin paljon
- melko paljon
- ei paljon eikä vähän
- melko vähän
- erittäin vähän

*24. Pystyin käyttämään kenttäteorian kurssien sisältöä hyödyksi muissa opinnoissani

- erittäin paljon
- melko paljon
- ei paljon eikä vähän
- melko vähän

- erittäin vähän

Työ

Sähkö- ja tietoliikennetekniikan osaston opintojen tarkoituksena on antaa valmiudet soveltaa annettuja tietoja erilaisissa tekniikan alan työtehtävissä. Tässä osassa pyritään selvittämään miten opintosi ja työtehtäväsi ovat kohdanneet.

*25. Työpaikkani (nykyinen työpaikkasi, jos olet ollut useammassa) vastaa sähkö- ja
tietoliikennetekniikan ohjelman koulutustani

- erittäin hyvin
- melko hyvin
- ei hyvin eikä huonosti
- melko huonosti
- erittäin huonosti

*26. Olen kokenut, että sähkö- ja tietoliikennetekniikan opinnoista on ollut minulle hyötyä
työelämässä

- erittäin paljon
- melko paljon
- ei paljon eikä vähän
- melko vähän
- erittäin vähän

*27. Olen kokenut, että kenttäteorian kursseista on ollut minulle hyötyä työelämässä

- erittäin paljon
- melko paljon
- ei paljon eikä vähän
- melko vähän
- erittäin vähän

28. Mikäli valitsit kohdan 'ei paljon eikä vähän','melko vähän' tai 'erittäin vähän',
miksi kursseista ei ole ollut sinulle merkittävää hyötyä?

*29. Koen, että olen saanut matemaattis-luonnontieteellistä perussivistystä opintojeni
aikana TKK:lla

- erittäin paljon
- melko paljon
- ei paljon eikä vähän
- melko vähän
- erittäin vähän

*30. Koen, että teknillistieteellinen ajatteluni on kehittynyt opintojeni aikana TKK:lla

- erittäin paljon
- melko paljon
- ei paljon eikä vähän
- melko vähän
- ei lainkaan

*31. Oltuani työelämässä valmistumiseni jälkeen olen kiinnostunut matemaattis-luonnontieteellisistä aiheista

- erittäin paljon
- melko paljon
- ei paljon eikä vähän
- melko vähän
- en lainkaan

*32. Vapaa-ajallani (työn ja opiskelun ulkopuolella) luen matemaattis-luonnontieteellistä
kirjallisuutta ja lehtiä tai seuraan kyseisen tutkimusalan kehitystä

- hyvin usein
- melko usein
- jonkin verran

- melko vähän
- en lainkaan

33. Minuun saa ottaa yhteyttä puolen tunnin haastattelua varten Sähköpostiosoitteeni (Osoite erotetaan muusta aineistosta ennen lomake-kyselyn aineiston käsittelyä)

Kiitos vastauksistasi!

Appendix 3. The first quantitative survey (as a translated summary in English)

Question number (refers to the original survey in Finnish, see Appendix 2)	Question	Options to answer/Scale
Background information		
1.	Gender	Female/male
2.	Year of birth	In four digits (e.g. 1984)
3.	Place of residence	1) the Finnish capital region (Helsinki, Espoo, Vantaa, Kauniainen) 2) other city in the capital region 3) a city outside the capital region
4.	My educational background	1) university degree 2) a degree at university of applied sciences 3) a degree at college level 4) upper secondary school vocational school or similar
5.	My work experience (in years) after graduation	1) 1-5 years 2) 6-9 years 3) 10-14 years 4) 15-20 years 5) over 20 years
6.	I have graduated from TKK Department of Electrical and Communications Engineering (ECE) in year (i) in major subject (ii)	in four digits written in the designated space in the survey
7.	I am a post-graduate student, my research area (to be written in a box)	1) not a post-graduate student 2) at university other than TKK 3) at another department at TKK 4) at ECE
8.	I am completing my post-graduate studies	1) not a post-graduate student 2) as a full-time student (graduate school, scholarship, with a job at TKK laboratory) 3) as a part-time student within my main job
Studies at TKK		
9.	How interested was I in scientific subjects when I started studies at TKK	Likert-scales [1-5] from 'Very interested' to 'Very little interest'
10.	How interested was I in electrical engineering when I started studies at TKK	Likert-scales [1-5] from 'Very interested ' to 'Very little interest'
11.	Electrical engineering was taught at TKK	Likert-scales [1-5] from 'Very well' to 'Very poorly'
12.	I received guidance for my studies when needed	Likert-scales [1-5] Always/Rather often/Often/Seldom/Never/I did not need any guidance
13.	If I received guidance for my studies, from whom I got it	Other students/Tutor-students/Student advisor/Study planner/Professors or other teaching personnel/else, from where?
Questions on electromagnetic studies (if you have had those in your degree)		

14.	I passed the Static field theory course	The number of times it took to pass the exam
15.	I passed the Dynamic field theory course	The number of times it took to pass the exam
16.	I passed the Applied field theory course	The number of times it took to pass the exam
17.	The courses in the Field theory	I have not passed the courses yet
18.	I participated in the Electromagnetic studies' lectures and exercises	Likert-scales [1-5] Always/Quite often/Often/Seldom/Never
19.	Considering the work load, the electromagnetic studies were	Likert-scales [1-5] Very easy/Easy/Not easy, not demanding/Rather demanding/Very demanding
20.	The work load of the courses in relation to the study credits was reasonable	Likert-scales [1-5] Completely agree/Agree/Disagree/Totally disagree
21.	I would have needed help for the following parts when taking the Electromagnetic studies	Aid to learn the substance of the lectures and theory/exercises/homework/group work/using MatLab/else, what?
22.	a. The content in the Field theory courses were	Too large/Reasonable/Too narrow
	b. The level of difficulty was	Too difficult/Reasonable/Too easy
	c. The clarity was	At the beginning of the course clear/unclear, why?
23.	The relation of electromagnetic studies to my other studies at ECE	Likert-scales [1-5] Very much/Much/Not too much or too little/ Little/Very little
24.	I could the substance of electromagnetic studies in my other studies at ECE	Likert-scales [1-5] Very much/Much/Not too much or too little/Little/Very little
Work		
25.	My current work is related to the studies at ECE	Likert-scales [1-5] Very well/Well/Neither well nor poorly/Poorly/Very poorly
26.	Electrical and telecommunications studies have been useful in my work	Likert-scales [1-5] Very much/Much/Not much not little/Little/Very little
27.	Electromagnetic studies have been useful in my work	Likert-scales [1-5] Very much/Much/Not much not little/Little/Very little
28.	If you chose an option 'Not much, not too little', 'Little', or 'Very little', could you describe why they have not been useful?	Open-ended answer
29.	I think I have gained scientific knowledge during my studies at ECE	Likert-scales [1-5] Very much/Much/Not much not little/Little/Very little
30.	I think my scientific thinking has developed my studies at ECE	Likert-scales [1-5] very much/much/not much not little/little/not at all
31.	After being in working life, I am interested in scientific topics	Likert-scales [1-5] Very much/Much/Not much not little/Little/Not at all
32.	In my free time (outside work and studies), I read scientific literature or journals, or I follow the development of a certain scientific field	Likert-scales [1-5] Very often/Often/Somewhat/ Little/Not at all
33.	I can participate in an interview (duration approx. half an hour) My e-mail address (The address will separated from other data before processing the answers)	E-mail address

Appendix 4. The invitation letter for the second survey

Sent in Finnish (text included in the invitation e-mail)

Hyvä vastaanottaja,

Tämän kyselyn avulla selvitetään TKK:n sähkö- ja tietoliikenneosaston opetuksen tieteellis-ammatillista tasoa, erityisesti kenttäteorian kurssien osalta. Kysely on osa laajempaa tutkimusta, jota teen sähkömagnetiikan laboratoriossa. Saatujen tietojen avulla pyritään kehittämään sähkö- ja tietoliikennealan perusopetusta sekä jatko- ja täydennyskoulutusta. Sinun mielipiteesi sähkö- ja tietoliikenneosastolla opiskelleena ovat erittäin arvokkaita!

Tämä kysely on lähetetty opiskelijoille, jotka todennäköisesti suorittavat DI:n opinto- ja vuoden 1995 tutkintosäännön mukaisesti. Vuonna 2005 otettiin käyttöön uusi tutkintosääntö. Aiemmassa tutkintosäännössä aloitetut opinnot on suoritettava loppuun 31.7.2010 mennessä. Saat lisää tietoa aiheesta osoitteista http://www.tkk.fi/Yksikot/Opintotoimisto/tietoaperus/1995_tutkintosaanto.html tai http://www.tek.fi/valmistu. Voit myös ottaa yhteyttä sähköosaston kansliaan, jos haluat kysyä omista opintosuorituksistasi.

Vastaa kysymyksiin valitsemalla omaa käsitystäsi parhaiten kuvaava vaihtoehto. Jos kohdassa saa valita useamman vastausvaihtoehdon, siitä on ilmoitettu erikseen. Joihinkin kysymyksiin voit itse kirjoittaa vastauksesi. Jos mietit, että perusopinnoistasi on kulunut aikaa etkä ehkä muista niihin liittyviä yksityiskohtia, koeta silti vastata! Pyydän, että vastaat jokaiseen kohtaan.

Kyselyn tulokset käsitellään luottamuksellisesti, ja niistä tehdään koko opiskelijaryhmää koskevia päätelmiä. Yksittäisen vastaajan tiedot eivät käy aineiston päätelmissä mitenkään ilmi. Jos olet kiinnostunut osallistumaan tämän kyselyn jälkeen tehtävään haastatteluun, kirjoita sähköpostiosoitteesi lomakkeessa viimeisenä olevaan kenttään.

Pyydän sinua ystävällisesti vastaamaan kyselylomakkeeseen mahdollisimman pian, kuitenkin viimeistään keskiviikkona 31.10.2007. Vastaamiseen kuluu aikaa noin 15 min. Suuret kiitokset etukäteen vastauksistasi!
Linkki kyselyyn:
http://www.dipoli.tkk.fi/ok/php/form.php?form=opetuksentasosahko07

Jos haluat lisätietoa tästä kyselystä tai koko tutkimuksesta, ota yhteyttä!

Ystävällisin terveisin,
Kirsti Keltikangas
Tutkija, KM, sähkömagnetiikan laboratorio, 09-451 2217,
sposti kirsti.keltikangas(a)tkk.fi

Appendix 5. The second quantitative survey (in Finnish)

Kysely TKK:n sähkö- ja tietoliikenneosaston opetuksen tieteellis-ammatillisesta tasosta

*pakolliset kentät

Taustamuuttujat

*1. Olen
- Nainen
- Mies

*2. Syntymävuoteni (vvvv)

*3. Asuinpaikkani
- pääkaupunkiseutu (Helsinki, Espoo, Vantaa, Kauniainen)
- muu Uudenmaan kunta
- muu kuin Uusimaa

*4. Peruskoulutukseni
- yliopistotutkinto
- ammattikorkeakoulu
- opistotasoinen tutkinto
- lukio
- ammattikoulu tai muu perusaste

*5. Työkokemukseni aktiitivisen opintovaiheen jälkeen
- 1-5 vuotta
- 6-9 vuotta
- 10-14 vuotta
- 15-20 vuotta
- yli 20 vuotta

*6. Olen tällä hetkellä
- vakituisessa kokopäiväisessä työsuhteessa
- vakituisessa osapäiväisessä työsuhteessa
- määräaikaisessa kokopäiväisessä työsuhteessa
- määräaikaisessa osapäiväisessä työsuhteessa
- itsenäinen yrittäjä/ammatinharjoittaja

- päätoiminen opiskelija
- työtön
- vanhempainlomalla/hoitovapaalla
- muutoin työelämän ulkopuolella, miten?

Vastaa seuraaviin kysymyksiin, mikäli valitsit edelliseen kysymykseen vaihtoehdon 1-5. Muutoin voit siirtyä kysymykseen 'Aloitin perusopintoni ...'

*7. Nykyinen työtehtäväni

*8. Pääasiallinen työtehtäväalueeni on

- Yleishallinnolliset tehtävät
- Strateginen yrityssuunnittelu
- Kaupalliset tehtävät kotimaassa
- Kansainvälisen kaupan tehtävät
- Opetus- ja koulutustehtävät
- Tutkimus- ja tuotekehitystehtävät
- Tuotesuunnittelu- ja muu konstruktiotyö
- Tuotannonsuunnittelu- ja valvontatyö
- Atk-suunnittelu (systeemi- ja ohjelmistotyö)
- Muut suunnittelutehtävät
- Käyttö- ja ylläpitotehtävät
- Laatutehtävät
- Projektitehtävät
- Konsultointi
- Muu, mikä

*9. Aloitin perusopintoni TKK:llavuonna

*10. Valmistumissuunnitelmani TKK:n Sähkö- ja tietoliikennetekniikan osastolta

- aion valmistua lukuvuoden 2007-2008 aikana
- aion valmistua lukuvuoden 2008-2009 aikana
- aion valmistua 31.7.2010 mennessä (ennenkuin minut siirretään vuoden 2005 tutkintosääntöön)
- olen vaihtanut opintoalaa/korkeakoulua
- en aio valmistua TKK:lta, miksi?

11. Valmistumiseni viivästymiseen ovat vaikuttaneet

- ☐ opintojen ohjaus (sen puute tai riittämättömyys)
- ☐ motivaatio
- ☐ oppimisvaikeudet
- ☐ ajankäytön hallinta
- ☐ opiskelutekniikka
- ☐ kurssivalinnat
- ☐ osittainen tai täyspäiväinen työnteko
- ☐ taloudelliset syyt
- ☐ perhetilanne (perheen perustaminen ym.)
- ☐ terveydelliset syyt
- ☐ jokin muu, mikä?

Opinnot Teknillisessä korkeakoulussa

*12. Miten kiinnostunut olin matemaattis-luonnontieteellisistä aineista aloittaessani
opinnot TKK:lla

- ● erittäin vähän kiinnostunut
- ● melko vähän kiinnostunut
- ● en vähän enkä paljon kiinnostunut
- ● melko kiinnostunut
- ● erittäin kiinnostunut

*13. Miten kiinnostunut olin sähkö- ja tietoliikennetekniikan opinnoista aloittaessani
opinnot TKK:lla

- ● erittäin vähän kiinnostunut
- ● melko vähän kiinnostunut
- ● en vähän enkä paljon kiinnostunut
- ● melko kiinnostunut
- ● erittäin kiinnostunut

*14. Mielestäni sähkö- ja tietoliikennetekniikkaa opetettiin TKK:lla

- ● erittäin huonosti
- ● melko huonosti
- ● ei hyvin eikä huonosti
- ● melko hyvin
- ● erittäin hyvin

*15. Sähkömagnetiikan alan kenttäteorian kurssit (staattinen, dynaaminen tai sovellettu
kenttäteoria) olivat mielestäni

- erittäin helppoja
- melko helppoja
- ei helppoja eikä vaikeita
- melko vaikeita
- erittäin vaikeita

*16. Ennakkokäsitykseni kenttäteorian kurssista/kursseista (ks. edellinen kysymys) ennen
kurssin aloitusta oli

- että kurssi olisi erittäin vaativa tai melko vaativa
- että kurssi ei ole vaativa eikä helppo
- että kurssi olisi melko helppo tai erittäin helppo
- minulla ei ollut ennakkokäsitystä kenttäteorian kurssista/kursseista ennen kurssin aloitusta

*17. Kenttäteorian kurssi/kurssit verrattuna muihin sähkö- ja tietoliikennetekniikan
kursseihin olivat mielestäni työmäärältään

- erittäin helppoja
- melko helppoja
- ei vaativia eikä helppoja
- melko vaativis
- erittäin vaativia

*18. Pystyin käyttämään kenttäteorian kurssien sisältöä hyödyksi muissa opinnoissani

- erittäin vähän
- melko vähän
- ei paljon eikä vähän
- melko paljon
- erittäin paljon

Työ

*19. Sähkö- ja tietoliikennetekniikan opinnoista on ollut minulle hyötyä työelämässä

- erittäin vähän
- melko vähän
- ei vähän eikä paljon
- melko paljon

- erittäin paljon

*20. Kenttäteorian opinnoista on ollut minulle hyötyä työelämässä

- erittäin vähän +
- melko vähän +
- ei vähän eikä paljon
- melko paljon
- erittäin paljon

Mikäli valitsit +-merkityn vaihtoehdon, voitko perustella miksi?

*21. Koen, että teknillistieteellinen ajatteluni on kehittynyt TKK:n opintojeni aikana

- erittäin vähän
- melko vähän
- ei paljon eikä vähän
- melko paljon
- erittäin paljon

*22. Oltuani työelämässä aktiivisen opintovaiheen jälkeen olen kiinnostunut matemaattis-luonnontieteellisistä aiheista

- erittäin vähän
- melko vähän
- en paljon enkä vähän
- melko paljon
- erittäin paljon

*23. Pystyn soveltamaan TKK:ssa oppimiani taitoja ja tietoja laajasti työssäni

- erittäin vähän
- melko vähän
- ei paljon eikä vähän
- melko paljon
- erittäin paljon

*24. Mielestäni opintoni TKK:ssa valmensivat minut työelämän haasteiden kohtaamiseen

- erittäin huonosti
- melko huonosti
- ei huonosti eikä hyvin
- melko hyvin
- erittäin hyvin

*25. Minulla on mielestäni työtehtävä, joka vastaa TKK:ssa saamaani koulutustani

- erittäin huonosti
- melko huonosti
- ei huonosti eikä hyvin
- melko hyvin
- erittäin hyvin

26. Minulle sopivin ammatillisen osaamisen kehittämisen muoto on

- ☐ työn kautta oppiminen
- ☐ lukeminen (kirjallisuus, oman alan ammattilehdet ym.)
- ☐ osallistuminen seminaareihin
- ☐ työpaikan sisäiset tai ulkoiset kurssit
- ☐ työpaikan ulkopuoliset laajat koulutusohjelmat
- ☐ korkeakoulun (esim. TKK:n) järjestämä täydennyskoulutus
- ☐ tieteelliset jatko-opinnot
- ☐ muu, mikä? _____

*27. Suunnittelen osallistumista oman alani täydennyskoulutukseen

- erittäin vähän
- melko vähän
- en vähän enkä paljon
- melko paljon
- erittäin paljon

*28. Olen osallistunut oman alani täydennyskoulutukseen

- erittäin vähän
- melko vähän
- en vähän enkä paljon
- melko paljon
- erittäin paljon

*29. Jatko-opintojen suorittaminen

- en ole harkinnut jatko-opintojen suorittamista
- saatan mahdollisesti suorittaa jatko-opintoja
- aion melko todennäköisesti suorittaa jatko-opintoja

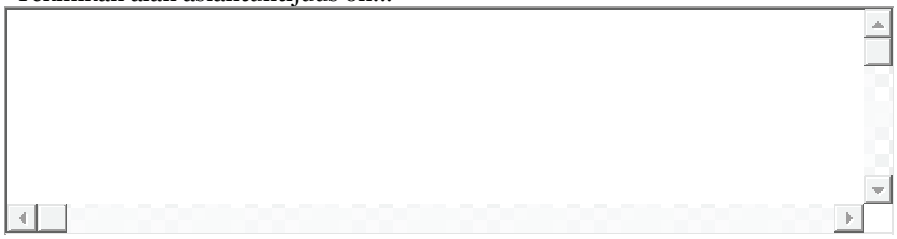
*30. Diplomi-insinöörinä minulla on paremmat työelämässä menestymisen mahdollisuudet kuin
muun akateemisen tutkinnon suorittaneena

- olen täysin eri mieltä
- olen melko eri mieltä
-
- en samaa enkä eri mieltä
- olen melko samaa mieltä
- olen täysin samaa mieltä

*31. Tekniikan alan korkeakouluopinnot kehittävät asiantuntijuuden synty-mistä

- olen täysin eri mieltä
- olen melko eri mieltä
- en samaa enkä eri mieltä
- olen melko samaa mieltä
- olen täysin samaa mieltä

32. Jatka seuraavaa lausetta mahdollisimman monisanaisesti (käytä yhtä tai useampaa
lausetta)
*Tekniikan alan asiantuntijuus on...



*33. Tekniikan alan korkeakouluopinnot kehittävät tieteellistä ajattelua

- olen täysin eri mieltä
- olen melko eri mieltä
- en samaa enkä eri mieltä
- olen melko samaa mieltä
- olen täysin samaa mieltä

34. Jatka seuraavaa lausetta mahdollisimman monisanaisesti (käytä yhtä tai useampaa

lausetta)
*Tieteellinen ajattelu on...

*35. Arvioi seuraavia ominaisuuksia miten tärkeinä pidät niitä omissa työtehtävissäsi/omalla alallasi

Vaihtoehdot:
1=ei lainkaan tärkeä
6=mielestäni erittäin tärkeä
eos=en osaa sanoa

	1	2	3	4	5	6	eos
1. oman alan tietojen hallinta	●	●	●	●	●	●	●
2. sosiaaliset taidot	●	●	●	●	●	●	●
3. ryhmätyö- ja yhteisölliset taidot	●	●	●	●	●	●	●
4. tietotekniset valmiudet	●	●	●	●	●	●	●
5. hyvä yleissivistys	●	●	●	●	●	●	●
6. oman toiminnan arviointitaito	●	●	●	●	●	●	●
7. kriittisen ajattelun taito	●	●	●	●	●	●	●
8. teorian soveltaminen käytäntöön	●	●	●	●	●	●	●
9. kokonaisuuksien hallinta	●	●	●	●	●	●	●
10. ongelmanratkaisutaidot	●	●	●	●	●	●	●
11. innovatiivisuus	●	●	●	●	●	●	●
12. itsenäisen työskentelyn taidot	●	●	●	●	●	●	●
13. tieteellinen ajattelutapa	●	●	●	●	●	●	●
14. teoreettinen analysointi	●	●	●	●	●	●	●
15. tiedonhaku ja sen soveltaminen	●	●	●	●	●	●	●
16. suulliset kommunikaatiotaidot	●	●	●	●	●	●	●
17. kirjalliset kommunikaatiotaidot	●	●	●	●	●	●	●
18. tehokkaat oppimistaidot	●	●	●	●	●	●	●
19. abstrakti ajattelukyky	●	●	●	●	●	●	●

*36. Arvioi seuraavia ominaisuuksia missä olet mielestäsi pääasiallisesti oppinut niitä

Vaihtoehdot:
1=työssä
2=korkeakoulussa
3=molemmissa edellisissä
4=muualla
5=vapaa-aikana

	1	2	3	4	5
1. oman alan tietojen hallinta	●	●	●	●	●
2. sosiaaliset taidot	●	●	●	●	●
3. ryhmätyö- ja yhteisölliset taidot	●	●	●	●	●
4. tietotekniset valmiudet	●	●	●	●	●
5. hyvä yleissivistys	●	●	●	●	●
6. oman toiminnan arviointitaito	●	●	●	●	●
7. kriittisen ajattelun taito	●	●	●	●	●
8. teorian soveltaminen käytäntöön	●	●	●	●	●
9. kokonaisuuksien hallinta	●	●	●	●	●
10. ongelmanratkaisutaidot	●	●	●	●	●
11. innovatiivisuus	●	●	●	●	●
12. itsenäisen työskentelyn taidot	●	●	●	●	●
13. tieteellinen ajattelutapa	●	●	●	●	●
14. teoreettinen analysointi	●	●	●	●	●
15. tiedonhaku ja sen soveltaminen	●	●	●	●	●
16. suulliset kommunikaatiotaidot	●	●	●	●	●
17. kirjalliset kommunikaatiotaidot	●	●	●	●	●
18. tehokkaat oppimistaidot	●	●	●	●	●
19. abstrakti ajattelukyky	●	●	●	●	●

37. Minuun saa ottaa yhteyttä haastattelua (30-60 min) varten
Sähköpostiosoitteeni (Osoite erotetaan muusta aineistosta ennen lomakekyselyn aineiston
käsittelyä)

Suuret kiitokset vastauksistasi ja ajankäytöstäsi!

Appendix 6. The second quantitative survey (as a translated summary in English)

Question number (refers to the original survey in Finnish, see Appendix 5)	Question	Options to answer/Scale
Background information		
1.	Gender	Female/male
2.	Year of birth	In four digits (e.g. 1984)
3.	Place of residence	4) the Finnish capital region (Helsinki, Espoo, Vantaa, Kauniainen) 5) other city in the capital region 6) a city outside the capital region
4.	My educational background	6) university degree 7) a degree at university of applied sciences 8) a degree at college level 9) upper secondary school 10) vocational school or similar
5.	I worked for no. of years after a period of active full-time studying	5) 1-5 years 6) 6-9 years 7) 10-14 years 8) 15-20 years 11) over 20 years
6.	I currently hold a	Permanent full-time job/permanent part-time job/temporary full-time job/temporary part-time job/an independent entrepreneur/full-time student/unemployed/on parental leave/outside working life for other reason, what?
7.	My current job is	Open-ended answer
8.	The current field of my job is	General management/ strategic planning/ sales tasks in Finland/ sales tasks abroad/ teaching and educational tasks/ research and development tasks/ product design and other design tasks/production planning and control/programming (system and programming tasks)/ other planning tasks/ maintenance and service tasks/ Quality/project tasks/consulting/ Other, what?
9.	I started my studies at TKK (in year)	In four digits

10.	My plan to graduate from ECE, TKK	I will graduate during the term 2007-2008/ I will graduate during the term 2008-2009/ I will graduate by 31.7.2010 (before the new degree regulation takes place/ I have switched to another university/ I will not graduate from TKK, why?
11.	The reasons affecting the delay in my studies	Guidance in studies (lack of it or insufficiency)/ Motivational reasons/ Learning difficulties/Time management/ Study techniques/ Course choices/Part-time or full-time working/Economic reasons/ Family-related reasons/Health reasons/some other, what?
Studies at TKK		
12.	How interested was I in scientific subjects when I started studies at TKK	Likert-scales [1-5] 'Very interested' to 'Very little interested'
13.	How interested was I in electrical engineering when starting studies at TKK	Likert-scales [1-5] 'Very interested ' to 'Very little interested'
14.	Electrical engineering was taught at TKK	Likert-scales [1-5] 'Very well ' to very poorly'
15.	Electromagnetic courses (static, dynamics, or applied field theory) were	Likert-scales [1-5] 'Very easy/Easy/Not easy, not demanding/Rather demanding/Very demanding'
16.	My expectation of the Field theory course/courses prior to starting	That the course would be very demanding or demanding/ not demanding or easy/ that the course would be rather easy or very easy/ I did not have any expectations before starting the course
17.	Considering the work load, the electromagnetic courses in comparison to other courses were	Likert-scales [1-5] Very easy/Easy/Not easy, not demanding/Rather demanding/Very demanding
18.	I could use the substance of electromagnetic studies in my other studies	Likert-scales [1-5] Very little/Little/Not little not much/Much/Very much
Work		
19.	Electrical and telecommunications studies have been useful in my work	Likert-scales [1-5] Very little/Little/Not little not much/Much/Very much
20.	Electromagnetic studies have been useful in my work	Likert-scales [1-5] Very little +/Little+/Not little not much/Much/Very much
	If you chose an option marked with + /would you define why?	Open-ended answer
21.	I think my scientific thinking has developed during my studies at ECE	Likert-scales [1-5] Very little/Little/Not little not much/Much/Very much
22.	After being in working life, I am interested in scientific topics	Likert-scales [1-5] Very little/Little/Not little not much/Much/Very much
23.	I can widely apply the skills and knowledge learnt at TKK	Likert-scales [1-5] Very little/Little/Not little not much/Much/Very much

24.	The studies at TKK prepared me to meet the challenges of working life	Likert-scales [1-5] Very poorly/Poorly/Not poorly not well/Well/Very well
25.	I have a work task which corresponds to the education I have received at TKK	Likert-scales [1-5] Very poorly/Poorly/Not poorly not well/Well/Very well
26.	The most appropriate form of my professional development is… (Respondents can choose several options)	Reading (literature, professional journals etc.)/ Participating in seminars/ Internal or external courses at work/ Large, external programmes at work/ Further education organised by a university (e.g. TKK)/ Post-graduate (scientific studies)/ Something else, what?
27.	I am planning to participate in further education in my own field	Likert-scales [1-5] Very little/Little/Not little not much/Much/Very much
28.	I have participated in further education in my own field	Likert-scales [1-5] Very little/Little/Not little not much/Much/Very much
29.	Post-graduate studies	I have not considered post-graduate studies/I may consider post-graduate studies/I will probably continue with post-graduate studies
30.	By being a Master of Science in Engineering I have a better chance of succeeding in working life compared to someone holding another academic type of degree	Likert-scales [1-5] Completely disagree/Disagree/Not disagree, not agree/Agree/Completely agree
31.	Studies in higher engineering education support becoming an expert	Likert-scales [1-5] Completely disagree/disagree/not disagree, not agree/agree/completely agree
32.	Engineering expertise is… Continue this phrase with as many words as possible	Open-ended answer
33.	Studies in higher engineering education develop one's scientific thinking	Likert-scales [1-5] Completely disagree/Disagree/Not disagree, not agree/Agree/Completely agree
34.	Scientific thinking is… Continue this phrase with as many words as possible	Open-ended answer

35.	*Assess the importance of the following skills and competencies in your field:* the knowledge of own field social skills group and networking skills computer skills general socio-cultural knowledge self-assessment critical thinking applying theory into practice systemic-thinking problem-solving skills innovativeness independent working skills scientific thinking theoretical analysing information management oral communicational skills written communicational skills effective learning skills abstract thinking	Options: 1=not at all important to 6=very important, and eos*=cannot say *en osaa sanoa = Cannot say
36.	*Surmise the following skills and competencies:* the knowledge of own field social skills group and networking skills computer skills general knowledge self-assessment critical thinking applying theory into practice systemic-thinking problem-solving skills innovativeness independent working skills scientific thinking theoretical analysing information management oral communication skills written communication skills effective learning skills abstract thinking	Options: 1=at work 2=at a university 3=combination of 1 +2 4=elsewhere 5=in free-time
37.	I can participate in an interview (Duration 30-60 min) My e-mail address (The address will separated from other data before processing the answers)	E-mail address

Thank you for answering and spending your time on filling out this survey!

Appendix 7. The invitation letter for the interview

(Sent in Finnish by an e-mail)

Hei,

sain nimesi ja yhteystietosi professori X:ltä, joka on työskennellyt Y-laboratoriossa entisellä Sähköosastolla. Pyytäisin sinua mukaan haastattelu-tutkimukseeni, jolla kerään aineiston väistöskirjaani varten Sähkölle (nykyisin Elektroniikan, tietoliikenteen ja automaation tiedekunta).

Olen taustaltani kasvatustieteilijä ja töissä Radiotieteen ja -tekniikan laitoksella (entiset sähkömagnetiikan, avaruustekniikan, teoreettisen sähkötekniikan ja radiotieteen labrat yhdistettynä). Tutkimukseni kohderyhmänä ovat valmistuneet sähkön DI:t ja osittain n-kurssin opiskelijat. Tutkimuksen rahoittaa tämä osasto ja Dipoli yhdessä, ja tuloksia on tarkoitus käyttää tämän talon perusopetuksen kehittämisessä, ja Dipolin koulutuksen suunnittelussa.

Tässä tiivistettynä tutkimukseni aihe

Electrical engineers? Perceptions on learning, expertise, and scientific thinking

The aim of the dissertation is to investigate electrical engineers' perceptions on learning, expertise and scientific thinking. The study supports the ideal of engineering education, which is, creating abilities in critical thinking and high-standard expertise when studying at TKK. The study examines engineers' perceptions on learning electrical engineering, and how learning is in relation with engineering expertise and scientific thinking. Competencies needed in creation of engineering expertise are examined as well. The outcomes of the study will serve both basic education and continuing education in electrical engineering.

Kysynkin nyt sinulta saisinko tulla haastattelemaan sinua tätä tutkimusta varten. Aikaa tähän menee noin tunti. Haastatteluaineistot tullaan käsittelemään luottamuksellisina niin ettei yhdenkään yksittäisen henkilön tiedot käy ilmi. Ota yhteyttä, mikäli haluat kysyä jotain tutkimukseeni tai pyyntööni liittyen!

yst.terv. Kirsti Keltikangas (puh. xxx xxxxxxxxx)

Appendix 8. Interview questionnaire

The written form merely for the use of the researcher
(Designed and asked originally in Finnish, translated into English for the purpose of the dissertation)

Haastattelurunko/*The interview framework*

Kysytään ensin haastateltavan taustatiedot (työkokemuksen pituus, valmistusmisajankohta, asuinpaikka (pääkaupunkiseutu/muualla) jne.)
Background information of the respondent (the length of work experience, time of graduation from TKK, place of residence [capital region/elsewhere]

Kerro miten sinä kiinnostuit tekniikasta? (missä vaiheessa / - kouluaika /lukio ym.)
How did you get interested in technology? (In which phase, in secondary school/in upper secondary school)

Miten sinä tulit sähkölle opiskelemaan?
How did you come to study electrical engineering at TKK?

Kuinka kuvailisit opiskeluaikaasi / miten kuvailisit sähkön opintojasi?
How would you describe your studies or your studytime at ECE?

Kerro työurastasi/*Describe your work career*
- Kuinka kuvailisit sitä? *How would you describe it?*
- Onko ollut käännekohtia? *Have you had any transition points in your career?*

Työn ja opintojen yhteys/Relation between work and studies
- Miten koet sähkön opinnot työelämässä / silloin kun valmistuit / välillä / nyt?
  How do you see the relation between your studies at ECE and working life / at the moment you graduated/in-between/ now (at the moment of the interview)?

Kompetenssit/osaaminen – *Questions on competencies/skills*
- Miten kuvailisit omia kompetenssejasi/*How would you describe your competencies?*
- Miten sinä kuvailisit omien kompetenssiesi kehitystä työuran aikana? *How would you describe the development of your competencies during your work career?*
- Miten haluaisit kehittää niitä (mitä ko. alalla tarvitaan ym)? *How would you like to develop them (those ones you think are needed in your branch)?*
- Voitko kuvailla niitä asioita jotka on vaikuttaneet kompetenssien kehitykseen? *Could you describe such issues which have affected your competence development?*

Miten kuvailisit tieteellistä ajattelua? Miten sitä tarvitaan työelämässä (kun on DI)? *How would you describe scientific thinking? How do you see it is needed in working life, in particular when being an engineer?*

Miten kuvailisit asiantuntijuutta? Entä tekniikan alan asiantuntijuutta? Onko sellaista [olemassa]? *How would you describe expertise? How about engineering expertise, do you think it exists?*

Millainen käsitys sinulla on missä vaiheessa olet itse oman asiantuntijuudesi kehityksessä?
How do you perceive your current phase in your expertise development?

Miten kuvailisit millaisten vaiheiden kautta urakehitys menee sillä alalla jolla olet?
How would you describe what type of phases there are in expertise development in your branch?

Mitä vaikutusta (tai onko ollut vaikutusta) sillä on että on nainen tekniikan alalla? (kysymys naisille)
Do you see it affects to be a female in engineering or in a technology field? (Asked from the female respondents)

Voitko kuvailla mikä sinulle on tärkeintä työssä / uralla/ tulevaisuudessa?
Can you describe what is most significant for you in your work / in your career / in the future?

Engineers are regarded as problem-solvers and experts in their technical fields. This expertise is acquired during engineering studies, whereas personal and professional competences are mostly adopted after graduation. The on-going changes require that such qualifications be learnt faster. Thus, technical universities need to 'produce' graduates with better qualifications. Yet, there is not enough knowledge of how engineers gain the seeds in expertise and professional competences in their studies. Likewise, universities need more research-based data on ways which competences could more effectively be integrated into the curriculum design. This research examines electrical engineers, their education and career. The results show that a foundation in engineering knowledge is built during the university studies, when students in general adapt an engineering mindset and identity. The results indicate there is a need to enhance knowledge of pedagogies incorporating expertise and professional competencies more systematically into the education.

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