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Developing of a Quadruple Model for Collaborative Research Actions between Higher Education Institutions and Industry

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Developing of a Quadruple Model for Collaborative Research Actions between Higher Education Institutions and Industry

Thesis for the degree of Doctor of Science in Technology to be presented with due permission for public examination and criticism in Auditorium 125, at Tampere University of Technology - Pori, on the 20 of June 2017, at 12 noon.

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Abstract

This research focuses on new, more practical models of collaboration between higher education institutions and industry in European universities. EU, the national governments and especially the national economies demand that there should be more goal-oriented actions for technology transfer and collaboration between HEIs and businesses so that the research and innovation results can be faster and more effectively capitalised. There is a research gap in combining the fluent partnerships, the applied technology research, the technology knowledge transfer and the integration of RDI and education with effective working methods. This research has concentrated on the modelling of research, development and innovation actions of HEIs, which aim at quality and practical RDI collaboration with enterprises as well as close integration between RDI actions and education.

The context of this research is the field of Finnish Universities of Applied Sciences (UASs) and in case studies the Satakunta University of Applied Sciences (SAMK) on the west coast of Finland. The goal of this research was to find connective factors and working methods, which can be utilised and focused on the research, development and innovation work at Finnish HEIs but also shared with other European universities in the future. In addition to all this the impact of the RDI work was studied in order to find the most effective factors affecting the integration of RDI and education and the engineering educators' professional development.

This research solved real world problems of enterprises and HEIs with innovative models. The main research method of this thesis has been the design science research. The modelling of the technology knowledge transfer as well as the technology research, development and innovation inside each project were based on design science research methodology. Altogether, the whole research process rested on an idea of a new HEI targeted model for collaborative research between HEIs and industry.

This research confirms that partnerships between HEIs and enterprises generate several benefits, like new learning outcomes and need based competence development for the personnel. The partnerships seem to require constant development of the processes and actions, but this research indicates that well-functioning partnerships create research-based knowledge to support innovation processes in the industry, foster new innovation

creation and recognise new opportunities for future collaboration. The research results encourage the HEIs to set their own goals more vigorously already in the beginning of the process.

The technology knowledge transfer modelling of this research has been based on applied research cases, in which the research knowledge and practical skills have been combined in order to answer the needs and challenges of the enterprises. The main goal of the practical research work has been to apply new technologies to new cases and to create new applications. The impacts of different applied research cases have been identified from the different perspectives of enterprises, HEIs and students. The modelling is based on the generalisations of these identified impacts. This research generated three different models for technology transfer. These models introduce new approaches for need and dialogue based technology knowledge transfer. The models focus on knowledge increase and innovations in SMEs. The models are non-linear, emphasise the meaning of need recognition and consist of many iterative cycles. This research states that the technology knowledge transfer deepens the collaboration between the HEIs and the SMEs. The model also aims at increasing the responsibility of the enterprises and supports push to pull transformation of the technology knowledge transfer.

As a part of this thesis, the experiences of engineering educators working as engineering researchers were studied. The results indicate that applied technology research work can increase the engineering educators' knowledge and practical knowhow remarkably. The educators highlighted new experiences and personal development. They found the applied technology research very arduous but also rewarding. This research states that the applied technology research work is an effective way of lifelong learning.

All things considered, this research was essentially a discourse of interactions between HEIs and enterprises, especially small and medium sized enterprises. The modelling of the actions and procedures have aimed at the interactions and collaboration that can add value for both parties. As the main contribution of this research the W^4 – a quadruple model for collaborative technology research activities between higher education institutions and industry – has been created. The purpose of the W^4 model is to create a WIN-WIN-WIN-WIN situation for the HEIs' regional innovation environment. When the HEIs and industry collaborate according to the model, all the participants, enterprises, HEIs, students and the surrounding society, win as the collaboration creates several advantages for all of them.

To conclude, the W^4 - a quadruple model for collaborative technology research activities between higher education institutions and industry – indicates clear benefits for enterprises, HEIs and students, who bring their needs and knowledge to the shared platform

of collaborative technology research activities and as a result of these activities they all gain new knowledge, practical knowhow, and ideas for innovation and development. When the enterprises openly bring their technology needs and challenges to the process of collaborative activities, the HEIs can identify and allocate their expertise to these purposes and engage students to work within the processes.

Keywords: University-Industry collaboration, partnerships, applied technology research, technology knowledge transfer, engineering educators' professional development

Preface

This thesis was carried out at Tampere University of Technology during years 2015-2017. The thesis summarises the research work that I have done over ten years on the constantly developing field of research, development and innovation at the higher education institutions. Doing the research and writing the papers was an eventful and inspiring journey that taught me a lot more than I could have ever foreseen.

I want to thank Tampere University of Technology for providing support and infrastructure for my studies. I want also to thank my supervisor Professor Hannu Jaakkola for all the scientific and practical advice. I am grateful to Satakunta University of Applied Sciences for giving me this chance to research and develop the field of applied technology research in higher education institutions. The most grateful I am to my supervisor Adjunct Professor Matti Lähdeniemi for his inspiring guidance, support, and encouragement but most of all for the trust that he has shown to my research work throughout the years. He has always been available when needed, helping with any request or question I had.

I am so grateful to so many colleagues for collaboration and professional support during the years of research work. I want to thank my boss Dean, Dr Petteri Pulkkinen for his support in finalising the thesis and in integrating the research results to the real world actions. I am also very grateful for Principal Lecturer, Dr Kari Laine for all the advice and encouragement he has given me but also for his invariably compassionate and peaceful attitude in all the work we do together. I am very grateful to the pre-examiners of this dissertation, Adjunct Professor Pentti Rauhala, University of Tampere, and Professor Peter van der Sijde, Vrije Universiteit Amsterdam, for their feedback and constructive comments regarding the manuscript. I am also very thankful for both Adjunct Professor Pentti Rauhala and Director, Adjunct Professor Juha Kostiainen, YIT Corporation, for agreeing to act as opponents in the public defence of my dissertation. I want also to thank Mrs. Johanna Palmgren for helping me to say things in English. I greatly acknowledge the European Union and Tekes (the Finnish Funding Agency for Innovation) for funding the research, development and innovation projects that have contributed to this research. I want also to thank High Technology Foundation of Satakunta for funding the finalising phase of this thesis.

I have had a privilege to work with many great persons during the years at Satakunta University of Applied Sciences. I want to thank my team mates and “boys” Joonas, Pauli, Tommi, Janika, Meri, Sari and Antti for the incomparable and inspiring team spirit. I am

also grateful for all the co-authors, especially Principal Lecturer Andrew Sirkka and Research and Development Manager Kati Katajisto, Seinäjoki University of Applied Sciences, for their indulgent guidance and support. I also thank all my other colleagues in higher education and interaction with industry field. In addition to colleagues, I would also like to cheer to all my friends for their ability to get my thoughts off the work time to time.

It is obvious that I would not be here writing this without all the support I have received from my family. I want to express my deepest gratitude to my parents, Eija and Markku, who raised me to be who I am and do what I want as well as appreciated education. I know that you have always believed in me. My biggest gratitude goes to my loving husband Juha and to our beautiful, clever daughter Karoliina, who have been my dearest supporters through the years of this research work. When Juha, Karoliina and my mother have taken care of the practicalities at home I have had the chance to concentrate on my research. I can never over emphasise their meaning in all this. This thesis is dedicated to you.

Rauma, spring 2017

Mirka Leino

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List of Publications

The thesis is mainly based on the following original publications (I-VIII), referred as italic references in the text.

I. Leino, M. & Laine, K. 2014. University Industry Interaction - Best Practice Model for Partnership. Conference Proceedings of the 13th International Science-to-Business Marketing Conference on Cross Organizational Value Creation.

II. Merilampi, S., Sirkka, A., Leino, M., Koivisto, A. & Finn, E. 2014. Cognitive mobile games for memory impaired older adults. Journal of Assistive Technologies, Vol. 8 Iss 4 pp. 207 – 223.

III. Valo, P., Leino, M., Kortelainen, J., Laine, K. & Iivonen, A. 2013. Intelligent Machine Vision System for Measuring Geometrical Characteristics of Reinforcing Bar. Proceedings of International Conference on Innovative Technologies, IN-TECH2013, pp. 161-164.

IV. Laine, K., Leino, M. & Pulkkinen P. 2015. Open innovation processes between higher education and industry. Journal of Knowledge Economy, Vol 6, Iss 3, pp. 589-610.

V. Leino, M., Katajisto, K. & Laine, K. 2015. Fostering Collaborative Innovation - Higher Education Institutions as Interpreters in Technology Transfer. 2015 University-Industry Interaction Conference Academic Proceedings: Challenges and Solutions for Fostering Entrepreneurial Universities and Collaborative Innovation.

VI. Leino, M. 2017. Technology Research and Innovation in Engineering Educators' Professional Development. European Journal of Engineering Education. Submitted.

VII. Leino, M. & Valo, P. 2016. Machine Vision in Smart Health and Social Care. In Book Merilampi, S., Sirkka, S. & Iniewski, I. (ed.) Introduction to Smart eHealth and eCare Technologies. Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742 CRC Press. pp. 129–148.

VIII. Laine, K., Leino, M. & Lähdeniemi M. 2016. Research Collaboration Fostering Mutual Values of Universities and SMEs. Academic Proceedings 2016 University-Industry Interaction Conference: Challenges and Solutions for Fostering Entrepreneurial Universities and Collaborative Innovation.

Author’s contribution

This thesis includes three papers published in international peer reviewed journals, four papers published in international peer reviewed conferences and one paper published as a chapter in an edited scientific book of ‘Introduction to Smart eHealth and eCare Technologies’. This chapter introduces the author’s contribution in each of these papers.

I. Article I “University Industry Interaction – Best Practice Model for Partnership” describes the research and development process of partnership based collaboration between higher education institutions and industry. In the article the partnership based RDI process is modelled and the model is described and evaluated with case examples from the students’ point of view. Mirka Leino is the corresponding author of the paper. She carried out and analysed the experimental work of the partnership R&D process with the help of the partnership board. Leino wrote the experimental work and co-wrote the methodology together with Laine. Leino and Laine modelled the partnership process and evaluated the model. Leino interpreted the results and was the main writer of the conclusions.

II. Article II “Cognitive mobile games for memory impaired older adults” describes the research and working methods and evaluates the effect of cognitively stimulating mobile games on the cognitive skills and recreation of older people with memory impairment. The article presents a synopsis of new cognitive recreation tools, an analysis of their effect and user feedback from the professional staff as well as potential new ideas for game developers. In this thesis the article points the importance of demonstrative and experimental applied research. Mirka Leino had the responsibility of the data analysis in this research. She conducted and wrote the results of the data analysis. Leino co-wrote the rest of the paper with Merilampi, Sirkka, Koivisto and Finn.

III. Article III “Intelligent Machine Vision System for Measuring Geometrical Characteristics of Reinforcing bar” describes the applied research process of a machine vision system carried out for the needs of a SME. In this thesis the article emphasises the importance of need based pilot applications in technology transfer. Mirka Leino planned and conducted the research in cooperation with Valo. Leino is the principal writer of the paper. The targets for the research as well as the conclusions of the research were written in cooperation with Valo, Kortelainen, Laine and Iivonen.

IV. Article IV “Open Innovation Between Higher Education and Industry” describes the first phase of the technology knowledge transfer modelling of this doctoral research. As the main outcome of the research, the article introduces two models of open innovation processes between a university and industry. The modelling and evaluation of the models are based on real practical open innovation processes. Mirka Leino was the main responsible in planning and carrying out the experimental research work. She wrote the research description and co-wrote the methodology together with Laine. Leino also created and wrote the models through a reflection process with Laine. The conclusions and impacts of the model were co-written in the team of Leino, Laine and Pulkkinen.

V. Article V “Fostering Collaborative Innovation - Higher Education Institutions as Interpreters in Technology Transfer” describes the second phase of the technology transfer modelling. The modelling is based on true innovation processes between HEIs and SMEs. The main outcome of the article is the innovation oriented model for technology knowledge transfer in HEI-SME collaboration with a view to foster collaborative innovation. Mirka Leino was the corresponding author of this paper. She wrote the experimental work of the research while Katajisto completed it with the perspective of another university. Leino, Katajisto and Laine wrote the methodology and created the model in cooperation around the same table. Leino was the principal writer of the results and conclusions collected by the writer team.

VI. Article VI “Technology Research and Innovation in Engineering Educators’ Professional Development” describes a research that aims at best practise identification of an educator-researcher combination. The article also compiles the advantages and challenges of this combined working method and presents the possibilities of utilising the new technology knowledge in engineering education as fluently and effectively as possible. The results of this research indicate that the participation in applied technology research may increase the engineering educators’ knowledge and practical knowhow significantly. Mirka Leino wrote the paper and is the corresponding author. She planned and conducted the experimental work and interpreted the results as well as concluded the paper.

VII. Article VII “Machine Vision in Smart Health and Social Care” is a chapter in a textbook “Introduction to Smart eHealth and eCare Technologies". The article describes the basics of machine vision technologies and introduces examples of demonstrating machine vision applications in health and social care. The article indicates the versatile impacts of the applied research work in the HEI environment. Mirka Leino wrote the paper and is the corresponding author. She planned the body of work, collected the material and concluded the paper. Valo had the responsibility of figure generation based on Leino’s ideas.

VIII. Article VIII “Research Collaboration Fostering Mutual Value of Universities and SMEs” introduces multiple case studies aiming at identifying of how a university can collaborate with SMEs and how both SMEs and universities can benefit from the collaboration. The article compiles the research findings of how the collaboration helps universities create strategic focal points for their research and make their education more dynamic. The article also points out how SMEs can add value by creating new innovations based on collaboration. The research indicates that in carefully considered collaboration, both, universities and SMEs, can create new networks that they can benefit also in novel ways. Mirka Leino wrote the research case description. Leino co-wrote the methodology as well as the results of the research in cooperation around the same table with Laine and Lähdeniemi. The writing team also concluded the paper together and the conclusion was written by Leino.

1 Introduction

The Finnish higher education institutions (HEI) have developed adequate methods for their basic and applied research since the Ministry of Education and Culture obligated them to carry out scientific and applied research as one of their main objectives. The universities of applied sciences (UAS), as the latest actors in the field of Finnish higher education institutions, have especially focused on applied research and regional development since the establishment of the universities of applied sciences, including the temporary UASs. One well recognised strength in HEIs' research work are the practical connections with local enterprises. In order to answer to the needs of the research and application development environment of the future, the UASs have to develop deeper collaboration with enterprises and more functional practises to create new partnerships. Also the technology and knowledge transfer must be focused on more multifaceted targets and need recognition as well as on answering and solving the challenges of the enterprises by using new technologies. Finally, the benefits of the university[1]-industry collaboration for all the enterprises, HEIs, students, HEI employees and the society must be underlined, emphasized or made visible so that all the stakeholders are able to perceive the importance and significance of it. The universities of applied sciences should have the courage to individualise the strategies to be suitable especially for the UAS and its stakeholders. This combination of needs and targets formulates the research gap for this doctoral thesis. As we all know, universal strategies do generate untargeted results.

1.1 Background

This doctoral thesis is based on over ten years of research experience at Satakunta University of Applied Sciences. The research has consisted of technology research supported by research and development of knowledge transfer, innovations and partnerships between HEIs and enterprises. The research knowledge has developed by national joint research with international influences. This research experience has laid a solid base for technology and engineering lecturing, which is observed as a third dimension in this research. The researcher and lecturer viewpoints have indicated

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[1] In this thesis the term "university" is used in its English language version with a broader meaning than "yliopisto" in Finnish. This includes no higher education policy interpretations.

how the results and effectivity of the research and project work highly depend on the working methods of the participating organisations and persons. These observations lead to this research of the factors and methods impacting the most the creation of innovations, remarkable research findings and functional collaboration. The goal is to find connective factors and working methods, which can be utilised and focused on in the research, development and innovation (RDI) work at Finnish HEIs but also shared with other European universities in the future. At the same time the impacts of the RDI work on engineering education must be identified and emphasised in order to raise the awareness of their added value to the engineering competences of graduating students.

Laine (2010) stated that the development of business, products and services will be more and more based on knowledge, and that requires deeper and more powerful collaboration between higher education institutions and industry. The knowledge based development requires new strategies, reward based action plans, functional processes and high integration of the knowledge transfer and the main processes in the higher education. In this kind of a knowledge based economy the collaboration based application development will most likely create knowledge. Knowledge creation, knowledge transfer and knowledge exploitation are following each other or even overlapping each other. This means that basic and applied research will be more combined. This will require confidential and committed partnerships with the view of mutual advantages and achievements. The discoveries of Laine's research set one background for this research. (Laine 2010.)

1.2 Context of the Research

The context of this research is the research of technology knowledge transfer between higher education institutions and enterprises based on different national and international procedures and their research. The Satakunta University of Applied Sciences (SAMK) on the west coast of Finland is discoursed as a case in case study level. SAMK is a multi-disciplinary and an international higher education institute of approximately 6,000 students and 400 employees. SAMK profiles itself as an industrial institution of higher education. Offering both Bachelor and Master level education as youth education as well as further education for adults, SAMK has a wide contact surface for the employment sector both nationally and internationally. SAMK provides research and comprehensive study programs in technology, business and administration and social and health care. According to SAMK's strategy (2016-2022) the three focus areas are Automation and Industry 4.0, Maritime Management as well as Services for the Ageing. Throughout the history of Universities of Applied Sciences SAMK has had a major role in developing RDI actions among Finnish UASs. The persistent and successful development work has also been rewarded repeatedly, e.g. for an innovative pedagogical solution, the Ministry of Education has granted the title of centre of excellence in university of applied science education for the SAMK Enterprise Accelerator for 2005-2006 and for SAMK's regional development impacts, the Ministry of Education has granted the title of centre of excellence in regional development for 2001-2002. (*Leino and Laine 2014*; SAMK 2016; The briefing of the Ministry of Education 2005; Satakunta University of Applied Sciences 2013)

The Council of the European Union requires more actions on the development of partnerships and deeper collaboration between educational institutes and enterprises. The Council also calls for facilitating the opportunities of lifelong learning opportunities (European Commission 2011). Davey et al. (2013b) studied the state of University Business Cooperation (UBC) in Finland. Their research reflected that the Finnish education and research are considerably appreciated. Both students, enterprises, academics and the public sector find UBC actions beneficial. Universities (refers to academics in Davey et al. report) see that UBC is most useful for students and then for enterprises and HEIs. Universities somehow see themselves benefitting the least. The Finnish environment for UBC is found positive, but there are still many challenges to be solved and developed. The enterprises do not recognise the ways of acting nor the time frames of UBC. Also the absorption capacity or indeed the lack of it, especially in the small and medium sized enterprises (SME), is seen as one obstacle. The development investments should also be focused on the operational activities. (Davey et al. 2013b)

Kautonen et al. (2015) found notable differences in collaboration modes and outcomes among the Finnish HEIs. While the traditional universities are mostly interested in IPR commercialising, the universities of applied sciences prefer the bidirectional collaboration development. From the regional point of view, the significance of the university industry collaboration is seen more distinct outside of the metropolis area. This encourages the provincial HEIs to uplift their efforts on multifaceted HEI-industry collaboration. (Kautonen et al. 2015)

Davey et al. (2013a) listed mutual trust and commitment, geographically short distances, existing relations between HEIs and business partners and the common interest of the stakeholders as the main drivers of UBC in Finland. In the same report the Finnish academics nominated the main benefits of the UBC for the HEIs: the improved employability of future graduates, the improved learning experience for students, the improved reputation in the field of research, the increased funding and the improved business performances. Ultimately, the universities need to develop the collaboration and interaction mode especially suitable for its region and for its fields of activity. (Davey et al. 2013; *Leino and Laine 2014*)

The requirements of increasing activities on the development of partnerships and deeper collaboration between educational institutes and enterprises called by the Council of the European Union (European Commission 2011), the significance of the university industry collaboration outside of the metropolis area (Kautonen et al. 2015) and the need for regional and activity field combined HEI-industry collaboration (Bradley et al. 2013; Davey et al. 2013; Leino and Laine 2014) indicate the evident research gap for this research. The innovation actions of HEIs need to be managed so that the results can be benefitted as widely as possible. This research focuses on fulfilling this research gab by finding the deeper factors of different dimensions on the HEIs' innovation environment and by combining the meaningful actions as a comprehensive operational model (W^4 model introduced in chapter seven). The purpose of this research is to integrate the innovation actions as a virtuous circle where the innovation actions support each other and that way continuously generate new innovations and more advantages for the enterprises, HEIs, students and for the surrounding society. This research provides new possibilities to refine the HEIs' collaboration with enterprises in order to exploit the efforts multidimensionally.

The research material in this doctoral thesis consists of the studies concerning the partnership development actions, the technology research and development projects as well as of the technology transfer projects, which have been conducted at the Satakunta University of Applied Sciences in 2008-2016. The main projects that contributed to this research are Tekes (the Finnish Funding Agency for Innovation) funded:

- NIR Camera Application Research in the Interface of Electronics and Welfare Technology (NIR-HE)
- International Technology Transfer pilot project at Satakunta University of Applied Sciences (KVT-SAMK)

as well as ERDF (European Regional Development Fund) funded:

- Applying Machine Vision Technologies in Industry and Higher Education (Pro Machine Vision)
- Universities of Applied Sciences as Interpreters of International Technology Knowledge Transfer for SME's (AMK KVTechTrans)
- Common Weal - Building up an innovation network on Welfare Technology – Well-being enhancement by personalised and service designed client technology (HYVÄKSI)
- Simulation environment – new extensions to automation of production

The last two of the projects act as the piloting and evaluating platforms for the models created in this research. These research projects set the research platform for this research while they provided dozens of cases to be studied. The actual research material consists of the cases, which were executed according to the design science research method, and for the modelling purposes, studied according to the case study research method.

1.3 Structure of the research

The structure of this doctoral research will be as following: After this introduction the research approach and main methodology of the entire research will be introduced. The partnership development process is then described in order to clarify the importance of the HEI-industry interactions in technology transfer. In the fourth chapter the different modes of technology research at universities of applied sciences have been presented, providing examples. The fifth chapter explains the entire process of developing the technology knowledge transfer model through different projects, recognised needs, cases, development phases, research pilots and dissemination. The sixth chapter concentrates on the engineering educators' professional development by technology research work and on the possibilities that the technology research work could offer for the engineering students. The seventh chapter combines all the development phases together as the quadruple model for collaborative technology research activities between higher education institutes and industry. The seventh chapter also analyses and evaluates the model in order to find the future research needs. Finally chapter eight concludes all this and discusses the significant parts by linking the results to the research questions, and fills the research gaps. In chapter 2.2 there is a description of the research bringing together the research questions, the papers describing the research work and results as well as this thesis, concluding the research results as a quadruple model for collaborative technology research activities between higher education institutions and industry.

2 Research approach and methodology

2.1 Problem description

The Finnish Universities of Applied Sciences have good relations with local enterprises. However, in innovation targeted technology research and development the functional collaboration requires more than just good relations. It requires operational partnership actions and the commitment of the partners. In order to succeed in the collaboration, the university should have its own models and structures for the partnerships.

Even though the partnerships are functional, they are not enough by themselves. The knowledge climate creation process within the partner enterprise has an important role in integrating the RDI objectives and actions of the enterprises and the HEIs. The universities need their own technology transfer models and procedures, which create the knowledge climate for successful innovation targeted technology research and development between the universities and enterprises. (Rauhala 2008; Tulkki 2008; Bradley et al. 2013)

At the same time the research, development and innovation work that is done for the enterprises' needs should be effectively beneficial also from the university's point of view. This means that the profit value of the knowledge increase must be harnessed for the good of the engineering education.

In this thesis the research problem description consists of needs for:

- functional partnerships between the university and enterprises
- procedures for innovation targeted technology research and development
- models for technology knowledge transfer
- ways of integrating the new knowledge as part of engineering education

These needs are studied from different perspectives and the research results are analysed and modelled in order to find the best practices for deeper and more meaningful collaboration. (Rauhala 2008; Bradley et al. 2013; Barry-Murphy and Sheridan 2012; Baaken and Schröder 2008; Feller et al. 2002)

2.2 Research objectives and research questions

This thesis concentrates on the deeper discovery of the most significant factors affecting the success of the innovations as well as the professional development and knowledge increase of the experts in the research work and in the enterprise collaboration of the higher education institutions. At the same time the integration of research and education is modelled from the point of view where the research work must have a positive impact on the quality of education. The years of empirical research and development work with a constructive approach provide this research with a good basis and a wide research material. In this thesis the term educator covers all the teachers, lecturers and professors, who share their knowledge with the students.

Conducing to the development of the applied technology research and technology transfer as well as the related enterprise collaboration combined with the engineering educators' professional development, the following distinct research questions have been identified:

1. Which factors are mostly affecting to the success and impressiveness of HEI-Industry collaboration? (Barry-Murphy and Sheridan 2012; Rauhala 2008; Tulkki 2008; Laine and Lähdeniemi 2007; Laine et al. 2008)

    a. How do the enterprises identify the universities of applied sciences as the experts of applied technology research and technology transfer? The enterprises must recognise the expertise of the HEI in order to begin the collaboration as smoothly as possible → the processes have to be described.

    b. How do the HEIs make sure that they are sufficiently familiar with the enterprises, their business and profit making within the region? The HEIs must know the enterprises so that the recognition of new knowledge and technology needs would flow as seamlessly as possible.

    c. How is the trust between HEIs and enterprises created so that the enterprises have the courage to bring their development needs and research challenges into the collective discussion?

2. Which factors mostly affect the collaborative applied technology research and innovation between HEIs and Industry? (Cohen and Levinthal 1990; Laine 2010; Nieto and Quevedo 2005)

    a. How do the HEIs absorb the agile procedures in initiating the new development projects?

    b. How do the absorptive capacity and the level of commitment of the enterprises affect the development works?

3. What kind of an innovation targeted technology knowledge transfer based model would be suitable for both HEIs and industrial SMEs? (Perkmann and Walsh 2007; Bradley et al. 2013; Minbaeva and Michailova 2004; Kuiken and van der Sijde 2011; Baaken and Schröder 2008)

4. Is it possible to model the new knowledge of HEI experts that is transferred promptly and fluently to higher education? While the applied research work and enterprise collaboration is developed, the UASs are recognising the challenge of internal knowledge transfer between RDI work and education. (Bryson and Hand 2007; Lähdeniemi et al. 2011; Crawley et al. 2007; Feisel and Rosa 2005; Winberg 2008)

The research questions guide the research thorough the wide research material. The final modelling of the collaboration is done by combining the research findings as a comprehensive but detailed model for collaborative technology research.

2.3 Research description

This research was conducted in order to develop deeper collaboration with enterprises, to find more functional practices for technology knowledge transfer between HEIs and enterprises and to find the most functional practices for integrating the research and education work within the universities and developing the educators' professional skills. The recognised research gab introduced in chapter 1.2 and the research questions presented in chapter 2.2 set the starting point for this research. Different research questions and their sublevels divided the research into narrower parts of partnership development, applied technology research, technology transfer modelling and intergration of research work and education. Each part of the research answered some of the research questions. The next figure (FIGURE 1) illustrates the connections between the research questions, the papers and this thesis.

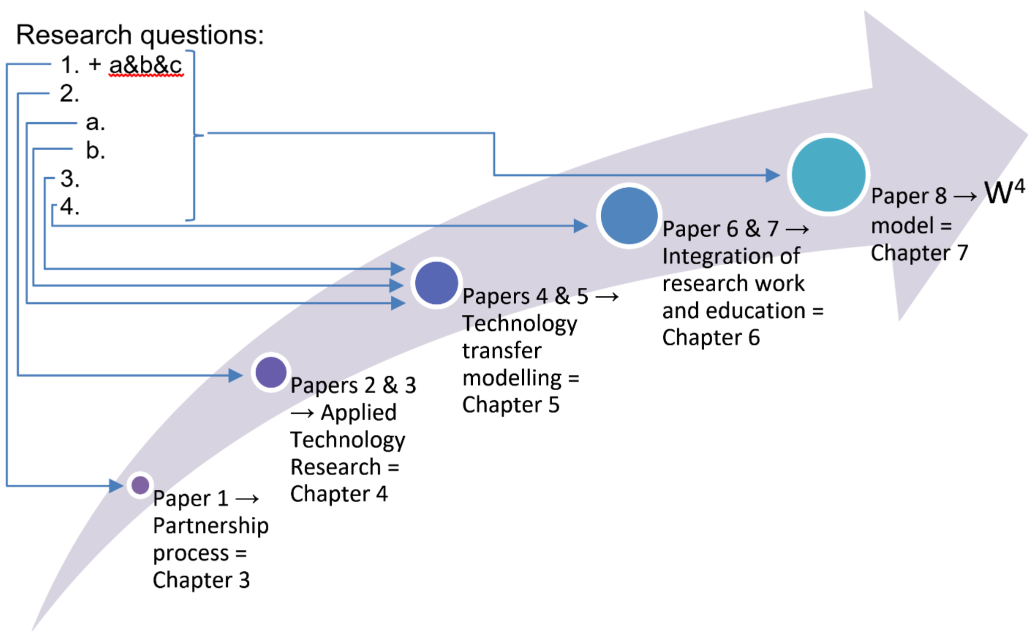

FIGURE 1 Connections of the research questions, the papers and this thesis

As FIGURE 1 presents, the parts of the research are described in the papers and the entire research is compiled in this thesis. The research questions are answered in the papers and the results are itemised in the corresponding chapters. The modelling process of the partnerships (paper 1 and chapter 3) and technology knowledge transfer (papers 4 & 5 and chapter 5) has been an evolving process with various phases and models. First 'the best practice model for partnership' presented the partnership based collaboration and examples of need recognition. Then 'the initial technology knowledge transfer process model' was created based on the technology research cases initially planned and studied. The next development step was taken with the goal of more open innovation. With the study of the following technology research cases the model for 'the innovation targeted participatory research process' was created. These two models were combined and tested with the new applied technology research cases. The test results highlighted the importance of absorptive capacity and disseminative capacity as well as the responsibilities of HEIs and enterprises in the different phases of the process. Based on these findings 'the innovation oriented model for technology knowledge transfer in HEI-SME collaboration' was created. All these models and other enlightening findings of this research were combined as the W4 model in this thesis. The W4 – a quadruple model for collaborative technology research activities between higher education institutions and industry - compiles the main findings of this research as a new model for HEI-enterprise collaboration with a diverse range of impacts to all the participants.

2.4 Research methodology

In this thesis the context of the research frame is the Finnish higher education institutions and the Satakunta University of Applied Sciences is discoursed as a case in case study. National and international partnerships are also a relevant part of the research frame. The constructive research methods have influenced the definitions of the research problems, which have been made during the years of empiric research. The research frame consists of mixed methodology (described more closely in chapter 2.4.2) with the levels of constructive research, design science research and case study research methods (FIGURE 2).

This research is fundamentally based on the constructive research approach. It has influenced the big picture but also all the research projects mentioned above. The research is constructive in its nature because it tries to solve the real world problems of enterprises and HEIs' with innovative constructions. This research states comprehensive research problems, which are then considered through multiple cases in order to find similarities and best practises. The recognition and construction of the most applicable procedures for process and technology development as well as for engineering educators' professional development provide guidelines for modelling. The research also introduces examples of the cases, links the results to the theory and demonstrates the usability in practise by constructive research. (Lehtiranta et al. 2015; Olkkonen 1993)

The main research method used in this doctoral thesis is design science research. The modelling of the technology knowledge transfer as well as the technology research and development inside each project are based on design science research methodology. Inside the research projects there have been dozens of cases, which have been studied according to the case study methodology. The variables of the research are at least the enterprises, the HEIs, the researchers, the technologies and the educators or lecturers. The next figure (FIGURE 2) illustrates the mixed methodology of this doctoral thesis. The research frame work sits inside the constructive research method. The design science research (DSR) works as the leading research method through the cases, and the case studies (CS) identify the best practices.

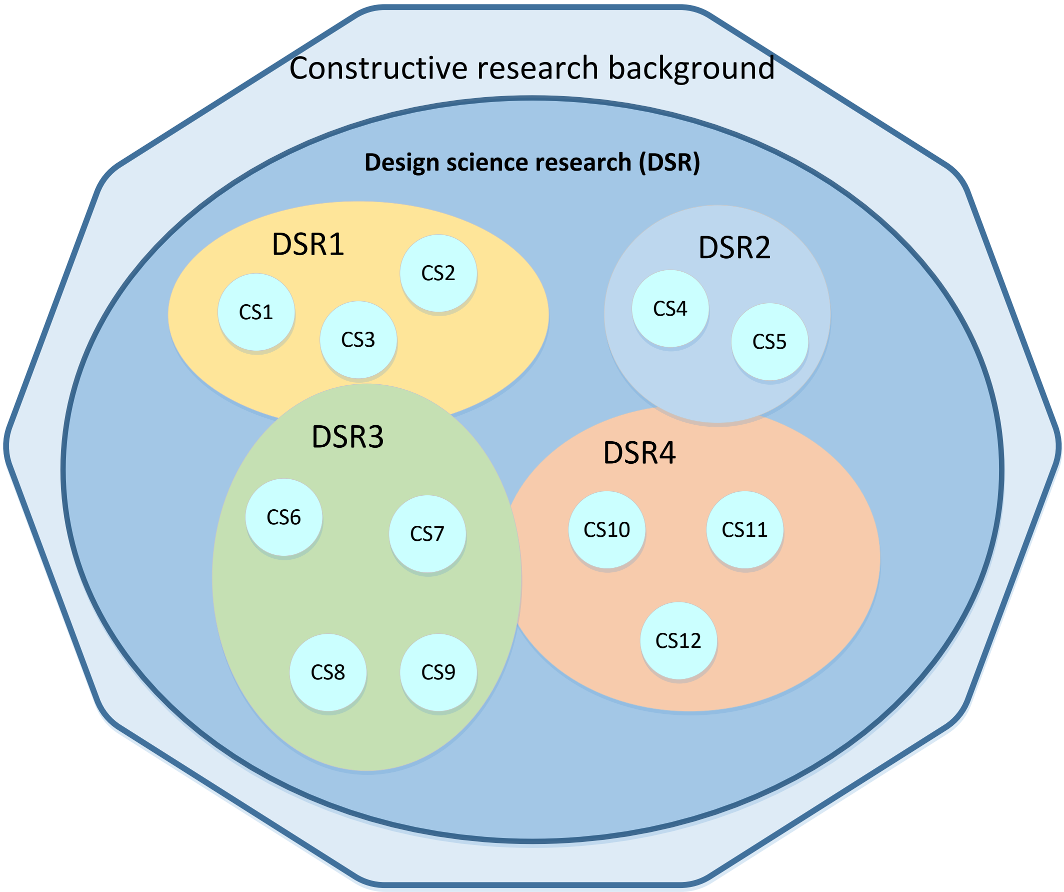

FIGURE 2 The research framework of this thesis

In addition to the main methodology of this doctoral research introduced in the figure above, the research is supported by some less meaningful research methods, like the inductive analysis of interviews, questionnaire and participative observation as well as mixed methods, combining qualitative and supporting quantitative methods and process modelling.

2.4.1 Design science research method

The leading research method affecting all the research and development introduced in this thesis has been the design science research. Both the modelling of the processes and the modelled cases have been highly influenced by design science research. The modelling was done with the scope of an innovative model as an artefact that could be applied widely to interactions between HEIs and

SMEs. On the other hand, the modelling was done according to the processes and cases, which were executed according to the design science research method.

Following Iivari (2010), March and Smith (1995) and later Hevner et al. (2004) stated that new constructs like ideas and concepts, new models like architectures and structures, new methods like functionality and behaviour as well as potential implementing all provide new knowledge on the artefact or innovation.

The design science research method is based on the problem solving paradigm. The design science research processes focus on innovative results that raise from the design and construction creativity of humans, and have evident needs. Design science research also tries to identify the creativity of designers and engineers and to focus it on application development. (Hevner and Chatterjee 2010; Wieringa and Morali 2012; *Leino, Katajisto and Laine 2015*)

The design science research method can be discussed through research activities and research outputs. The artefacts of the process, like constructs, models, methods, and pragmatic instantiations, are seen as the research outputs. It is stated that in engineering sciences the artificial phenomena play a much wider role than the natural phenomena. Combining artificial phenomena with human creativity leads to artefacts designed to meet the needs of the subject. The research activities like building, evaluating, theorising, and justification, are seen as the other dimension. The artefacts like systems, devices and applications are built and evaluated in as goal-oriented way as possible. At the same time these artefacts are theorized and the theories are justified. (March and Smith 1995; *Leino, Katajisto and Laine 2015*)

Hevner et al. (2004) state that in design science research the novel knowledge and understanding come from the design process of an artefact. Hevner et al. define very clear guidelines for design science research process following the next steps:

1. Design as an artefact
2. Problem relevance
3. Design evaluation
4. Research contributions
5. Research rigor
6. Design as a search process
7. Communication of research

First of all, Hevner et al. point out that the whole design science research process rests on an idea of an artefact that should be designed. Next, it is very important to ensure and show that the problem is relevant. The problem relevance should be defined for example by comparing the present state and the future state of the artefact and then by defining the relevance of the change between these states. (Hevner et al. 2004)

Then, the evaluation phase of the design is based on the analysis of the artefact's usefulness, quality and/or effectiveness. The evaluation methods may be observational, analytical, experimental or descriptive. After all, in design science research there must always be a clear result like a new artefact, new knowledge and/or a novel method. Research rigor refers to the rigorous construction and evaluation methods used in the research work. It is necessary to choose the appropriate techniques to design and methods to test and evaluate the artefact. (Hevner and Chatterjee 2010)

Eventually, the design process is a knowledge search process where useful and available methods are used to find requisite information needed to accomplish a solution as practical as possible. After the design process it is essential to introduce all the significant knowledge of the design work to both technology-oriented and management-oriented groups of interest. (Hevner et al. 2004)

In this thesis the modelling of technology knowledge transfer is highly affected by the design science research method. The quadruple model for collaborative technology research activities between higher education institutions and industry brings the design science research to the next level of collaborative research activities with deeper understanding of knowledge needs.

2.4.2 Case study research method

The case study research method is often associated with social sciences but it is also found useful in this kind of technology bound research where the goal is to both study technology cases and identify behavioural best practices. In case study research it is the extensive descriptions of social and behavioural phenomena which are in focus. In the case study research the goal is to plan and design useful cases and then prepare them so that the collection of data can be done as effectively as possible. The data is analysed and evaluated in detail and the results are shared related to the prepared research questions. (Yin 2014)

The case study research method was chosen for this research because it concentrates on contemporary actions and aims at identifying behavioural habits and potential procedures which lead to innovations and professional development. Following Yin's study (2014) in this research the case studies were used for best practise identification. All the cases were planned and prepared combined with design science research and case study research methods in order to find and set out the answers for the research questions. The actual technology research and development as well as the technology knowledge transfer development were executed by following the design science research method. The most important role of the case study research method was to clarify the meaning and synergy of the actions. During and after the case execution the data was collected through interviews and best practise identification process. The data analysis and evaluation was used in identifying the most significant factors of both technology knowledge transfer and technology research as well as innovations in the professional development of engineering educators.

2.5 Technology research and innovations in higher education institutions

The literature review for this doctoral thesis follows Creswell's (2014) methods of literature review. In addition to this, Liston's (2006) model with four phases was used in the practical approach. In the first phase the initial literature review was made, adopting the terminology and detecting the most significant topics for the research in more than 150 papers. In this phase the initial research questions were set. Next, the exploratory literature review was made by identifying the more specific papers and references as well as focusing on the terminology in nearly 80 papers. This helped in refining the research questions. The third phase was the focused literature review of 55 papers, which assisted in the composing of the final references and in analysing them. The refined literature review of 35 papers was made in parts when writing the papers for this research. (Creswell 2014; Liston 2006; Kitchenham et al. 2009; Kitchenham 2004)

According to the literature review there are plenty of research articles concerning technology and knowledge transfer, innovation environments as well as collaboration between higher education institutions and enterprises. The most observable thing in these articles is that they have obvious aspect differences. For example, the continent, the country, the main industry of the area, the university's top fields of knowhow and the research area affect the operating model and its most important parts. The literature review for this doctoral thesis raises the articles which can be cited on a general level.

Barry-Murphy and Sheridan have observed that higher education institutions have significant research, education and infrastructures but unfortunately enterprises, communities or even the society may not know how to benefit from the knowledge and development possibilities. (Barry-Murphy and Sheridan 2012)

Rauhala (2008) and Tulkki (2008) emphasise the importance of HEIs' RDI work on a regional level and adduce the significance of partnership based collaboration instead of a separate project. Baaken and Schröder (2008) and The Partnering University Approach (2011) emphasise the meaning of quality and strategical choices in successful technology transfer. Laine (2008b) states that teachers and students are found to have an important role in innovation while Rauhala (2008) also underlines the integration of RDI work and education. (Rauhala 2008; Tulkki 2008; Baaken and Schröder 2008; Laine 2008b)

Feller et al. (2002) wrote that enterprises participate the research projects of universities and research institutes mainly because they want to get in touch with quality research knowledge. Meanwhile, the enterprises prefer the research projects to be more short term and to focus more on applied research. This is a meaningful note for the universities of applied sciences when choosing enterprise partners for research projects and communicating with them. (Feller et al. 2002)

Cowan and Zinovyeva (2013) have made some conclusions that are also significant for the regional HEIs. They state that regional universities tend to increase the amount of innovations in local enterprises. On the other hand, Žemaitis (2014) considered the collaboration especially from the enterprise's point of view and stated that high technology innovation requires wide collaboration, creative thinking and advanced knowledge absorption methods from the enterprises. This thesis takes a stand on identifying these features particularly in the small and medium sized enterprises.

Buganza et al. (2014) conclude that the relationships between SMEs and universities vary across the different phases. There are two main phenomena that explain why some enterprises are more able than others to engage in complex collaborations with universities and research centres. The first phenomenon relates to step-by-step development, trust, partner familiarity and technological familiarity. The enterprises that are able to push the collaboration until the research phase follow a progressive collaboration model. This increases the likelihood of a successful collaboration. The second phenomenon relates to technology management and project management capabilities of the enterprises. These capabilities allow them to reduce the cost and risk associated with defining their needs correctly, assessing the results and increasing the chances of successful collaboration. (Buganza et al. 2014; *Leino and Laine 2014*)

On March 19 2014 the European Commission published a fact sheet "Advancing Manufacturing paves way for future of industry in Europe". In this fact sheet the smart automation based solutions are seen as essential factors for a successful European industry. Technology transfer and demonstrations of new technologies will bring the new smart solutions as parts of manufacturing and business actions as soon as possible. For SAMK this is a very good message from the EU, as new technology demonstrations have been one of the key areas of applied technology research at SAMK for several years. The demonstrations are discovered as a useful method to disseminate the latest technology knowledge to the enterprises and in that way initiate new research projects aiming at applying these new technologies. (Advancing Manufacturing paves… 2014)

Earlier the technology transfer was based on linear models. The created technologies, which were transferred to the enterprises, were based on the research results of the universities. Technologies were widely protected and commercialised. Harmon et al. (1997) listed five types of technology transfer processes based on where the transferred technology was initiated, whether the target enterprise of technology transfer was an existing one or formed for that purpose, and based on the nature of the relation between the source and target of the transfer. These types are:

1. Technology is created at the university and transferred to an existing enterprise

2. Technology is created at the university and transferred to an existing enterprise that is developed for that purpose

3. Technology is created at the university and sold to a venture capital enterprise

4. Technology is created at the university and a new enterprise is created to sell it

5. Technology is developed by the enterprise, but it needs help on specific fields of expertise from the university to utilise the technology. (Harmon et al. 1997; *Leino, Katajisto and Laine 2015*)

In 2007 Perkmann and Walsh concluded that traditional technology transfer between universities and enterprises has focused mainly on IP rights, patents, licensing and commercialization of the research results whereas modern technology knowledge transfer means much wider actions with different operation channels and mechanisms. These channels and mechanisms are used to describe cognitive and social paths of knowledge, information and dissemination of other resources, and further development in collaboration between enterprises and HEIs. (Perkmann and Walsh 2007; *Laine, Leino and Pulkkinen 2015*)

Technology transfer has come to its turning point in the 2010s. Bradley et al. (2013) bring out insufficiencies of traditional, linear technology transfer. They also point at the increasing importance of technology transfer for economic development and innovation. Bradley et al. suggest that HEIs must create their own technology transfer models to support and boost their research activities in order to better exploit them with the enterprises. This one suggestion became as one of the main research gap notifications in the literature review and it led into the specific research questions. (Bradley et al. 2013; *Laine, Leino and Pulkkinen 2015*)

This literature review indicated and later confirmed the research gap and the goals of filling it. Summarily, the research gab indicates that the innovation actions of HEIs need to be managed so that the results can be benefitted as widely as possible. This research focuses on filling this research gab by finding the deeper factors of different dimensions on the HEIs' innovation environment and by combining the meaningful actions as a comprehensive operational model. One of the most important research goals of this doctoral thesis is to identify, to solve and to combine the changes, the challenges and the procedures of future technology and knowledge transfer in HEI-SME collaboration as a comprehensive model. It also set the goal for finding the most feasible and the most effective channels and methods for technology transfer in the context of need recognition based applied technology research.

2.6 The role of universities and engineering educators in the field of research, development and innovations

The role of universities and engineering educators in the field of research, development and innovation is observed from several directions in this research. How should the university and educators collaborate with enterprises? How do the students learn the actions and procedures of research, development and innovation as inspiringly as possible? What kind of actions enable the most useful results from the universities' point of view? Do the multidisciplinary HEIs have versatile possibilities for bringing different views and wider knowledge to innovations and thereby to educational actions?

The modelling of partnerships in this research focuses on processes which aim at the creation of innovations by creating new valuable combinations of internal and external knowledge. Innovation management research typically models the development paths of the idea, the people and organisations involved in the interaction and the transactions between the operators, the outcomes of the innovation process, and the context of innovation. Although innovation paths are individual, general elements suitable for the most similar processes are presumably discovered. (Tidd et al. 2005; Van de Ven et al. 2008)

From the universities' point of view, the engineering educators' life-long professional development is an essential factor in the sufficient and successful engineering education. In the literature review the articles on the strategic design of engineering education concern mainly the teaching methods, the fundamental objectives of the education and learning studies. However, the empiric research based presumption of this research is that the professionalism and subject engagement of the educators play a significant role in motivating and inspiring the students (Bryson and Hand 2007; *Leino 2017*). In addition, the results of the INSSI project have influenced this research with its modern aspect of engineering education (Lähdeniemi et al. 2011).

Crawley et al. (2007) suggest that the engineering educators' practical and industrial development experiences tend to be limited although they are supposed to have a background in the industry. The engineering students also have increasing needs for hands-on experiences and real-life industrial practice. Crawley et al. focus on faculty competence enhancing from the point of view of organisational possibilities. They listed action examples for enhancing faculty competence:

- Engineering educators' temporary work placements in industry
- Partnership combined research and education projects with industrial partners
- Practical knowhow requirement as one of the hiring or promoting criteria
- Educational programs like workshops and seminars for the existing faculty members
- Talking industrial engineers into part-time educators (Crawley et al. 2007; *Leino 2017*)

Lattuca et al. (2006) remind that one of the most important learning outcomes of engineering education is practical knowhow, and the role of educational laboratories in gaining practical knowhow is undisputed. One opinion of Feisel and Rosa (2005) is that there are many human factors complicating the supply of laboratory education. They assume that laboratory education and different practical exercises require a higher level of motivation and practical professionalism than traditional lecturing. They also notify the careful planning and writing of the laboratory instructions. Feisel and Rosa state two main reasons why laboratory education is more and more challenging today: 1. the complexity and cost of equipment are increasing all the time, and 2. the motivation of the laboratory educators varies. On the other hand, computer integration increasingly enables various possibilities, like simulations, remote control of equipment, and automated data analysis. In the big picture they emphasize the necessity of practical knowledge of the engineering educators in creating effective laboratory experiences for the students. (Feisel and Rosa 2005; *Leino 2017*)

Winberg (2008) emphasises both practical engineering knowledge and pedagogical knowledge. Winberg's figure of "Identity shifts in the process of acquiring pedagogical content knowledge" (FIGURE 3) presents one of her conclusions. The figure qualifies the levels of knowledge into two levels and shows that an engineering educator must have both high engineering knowledge and high pedagogical knowledge. Without high pedagogical knowledge one is "only" an engineering expert and without high engineering knowledge one is "only" a facilitator.

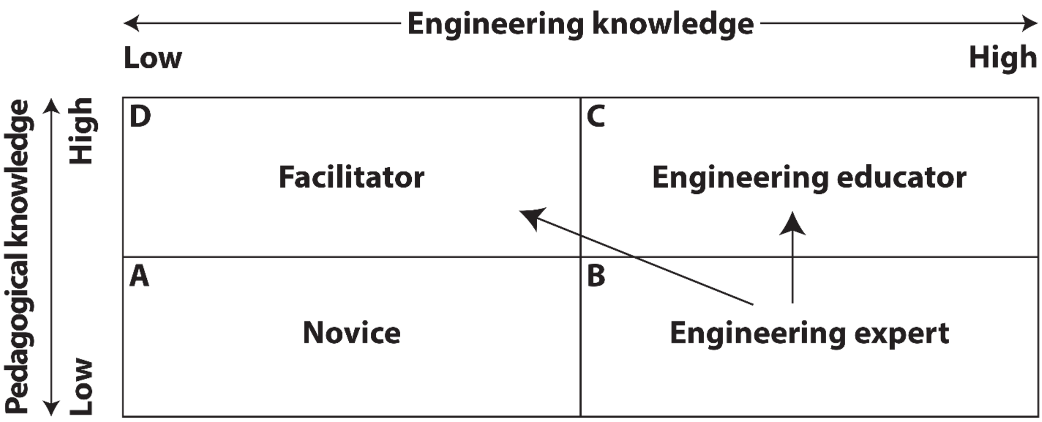

FIGURE 3 A modification of Winberg's (2008) figure of Identity shifts in the process of acquiring pedagogical content knowledge

In 2000 Susan Loucks-Horsley wrote:

> "If technology teachers do not understand deeply the technology concepts they are trying to teach, one cannot expect their students to learn." [2]

In this thesis this is seen as one of the fundamental observations in engineering educators' professional development. In this constantly changing technology world the educator is all the time required to have the courage and wisdom to let the outdated knowledge go as well as to absorb the novel knowledge. The highly refined all-round educators generate new professionals. (*Leino 2017*)

The literature review indicates that engineering educators' professional development really requires research and field-specific solutions in order to ensure the practical knowhow of the future engineers. Life-long learning and professional development increase motivation, understanding and hands-on

2 Loucks-Horsley, 2000

experiences, which again enable educational laboratories, practical learning as well as motivated and inspired students. (*Leino 2017*)

All things considered, the literature review indicates an evident research gap for this research. HEIs need an overall model for the technology research collaboration between HEIs, enterprises and students. The model should combine the best practices and different modes of collaboration in order to answer the varying needs and situations of the collaboration and research topics. The modelling should be based on research concerning partnership processes, applied technology research, technology transfer modelling and the engineering educators' professional development. The research questions set by the literature review and guiding through the wide research material are introduced in chapter 2.2.

3 Developing partnerships for fostering interactions between higher education institutions and industry

As one part of this thesis the RDI collaboration based partnership process is modelled and analysed. The model is based on student projects, theses, work placements and technology evaluating processes performed by the students and guided by the expert lecturers but also on more demanding research projects conducted by the researchers. As the main outcome of this chapter the best practice model for the partnerships between universities and industry is created and evaluated. The model should be pragmatic and have practical implications. There will be many potential benefits of using the model for both industry and higher education, but the most important purpose of the model is to foster the interactions between higher education institutions and industry.

HEIs have developed multiform interactions with the local industry for years. The interactions have evolved into partnerships with some of the enterprises. Typically, these enterprises are enlightened operators in their field of industry. The partnerships are continuously developing processes, and the climate and trust creation is a prominent part of them. The trust between the university and enterprises increases with small and specific action steps. One well tried way of promoting the trust is to focus on the enterprise's research, development and innovation actions. In this kind of university-industry partnerships the RDI needs of the enterprises are constantly identified. Need recognition is also a good way of creating the shared knowledge climate. Based on the identification, the most potential development tasks are defined and prioritized. This persistent work creates a solid base for developing the RDI collaboration. The partnership board is an essential operator in this identification process while students are the main operators in the implementation of the tasks. (*Leino and Laine 2014*)

3.1 Trust creation

In modelling of the partnerships and partnership processes in this thesis, the trust and knowledge climate creation is found to be very important. Trust in relationships is a complex issue appearing on a personal, team or organisational level. There are also dynamics between personal and organizational levels. The literature review disclosed that there are several researches focusing on people's conceptions of trust. However, there seem to be less researches exploring how trust is created in collaboration and what kind of actions create trust. (*Leino and Laine 2014*)

One of the first observations in this research was that the trust creation is necessary on some level before the partners are willing to share knowledge openly and spontaneously. The knowledge climate creation fosters trust creation and vice versa. Trust can be defined as a three-dimensional factor. These dimensions are competence, goodwill, and identity, where competence is the most important (Blomqvist 2002, 178-190). Wilson and Wilson (1994) listed immediate problem solving, frequent contacts, honest communication and wide relationships developing as good ways of creating trust. Collaboration competence is seen as a core competence for innovation (Blomqvist and Levy 2006, Miles et al. 2005, 2006). In the future, the success of innovative SMEs is based on technology and trust (Miles et al. 2005, Laine 2010).

Time, trust and territory are needed before the creation and transfer of knowledge can happen in innovation collaboration (Miles et al. 2000). Territory here refers to the personal areas of knowledge that are identified and accepted. Lewicki and Bunker (1996) separate trust into three levels:

1. Calculated trust
2. Knowledge-based trust
3. Identification-based trust

Transition to a higher level of trust takes time. Predictability creates trust and predictability is created by sustained social relations. (Lewicki and Bunker 1996; Bews and Martins 2002.)

A prominent remark from the literature is that calculus-based trust is based on a hope that positive actions will be rewarded and on the fear that negative actions will be punished. Lewicki and Bunker (1996, 120) point out that this leads to situations where the deterrent elements rule over the reward-aimed elements. Knowledge-based trust, on the other hand, is a developing path, which rests on acquaintance that creates predictability. The partners know each other's knowledge because of the long collaboration (Lewicki & Bunker 1996, 121). In this kind of a trusting relationship with confidential knowledge climate even negative outcomes can be approved. The highest level of trust is called identification-based trust and it is based on knowing and understanding the needs of another on a deep level. This leads to circumstances where mutual communication helps the partners to effectively act for each other. (Lewicki & Bunker 1996, 123). Identification based trust is a form of trust where one party will protect and promote the interests of another. On this level, trust is usually seen in more intense relationships. Contracts are typically minimal on this level. (Robbins, 2001)

3.2 Partnership process

Because of the public, non-profit status and responsibility for regional development set by The Ministry of Education and Culture, HEIs conduct public interest collaboration between higher education institutions, research and development centres and business sector.

SAMK has been a part of the cluster development and networking as well as upgrading the knowledge management activities. This has set a solid foundation for partnerships with the most active enterprises. The target of the modelling is that the same partnership model can be used with private and public organizations and clusters. Partnerships are seen as future-oriented collaborations that use several elements of the interaction model to benefit both parties. (Laine and Lähdeniemi 2007; Laine et al. 2008)

The strategic partnerships are started with several types of organisations. These organisations are large enterprises, SMEs and public organisations. In the beginning there were no clear goals for the partnerships, but there was the presumption that partnerships would create long lasting, deeper and more beneficial and flexible collaboration than ad hoc collaboration. Another goal was to centralise most of the connections on one contact person per partner to avoid dispersed contacting. Dispersed contacting tends to confuse partner organisations because same type of contacts may come simultaneously from several people. In this thesis the partnerships are modelled on a general level and examples of the two of the first and most active partnerships are described. (*Leino and Laine 2014*)

The partnership formulation begins with a meeting, where the senior management sets the goals for the partnership on a strategy level. They deal with both acute and future needs of partners with a time frame of several years. The actual partnership is based on a contract with a list of contact people, milestones and responsibilities of actions. The partnership based collaboration can have several forms, e.g. adaptive work placements, technology demonstrations, focused visits, Research and Development seminars, projects made by students and personnel, theses as well as continuous personal and organisational knowledge development and transfer. All these are used to fulfil the needs of the partners. The general target of comprehensive partnerships is to be productive and beneficial. (*Leino and Laine 2014*)

3.3 Partnership process model

Partnership establishment consists of five phases: identification of potential partners, partnership contract, partnership board, collaboration and evaluation. The partnership process model, where the university is in charge of the partner identification, is presented in FIGURE 4. In this research, the partnership process model sets an example of the most effective enterprise collaboration.

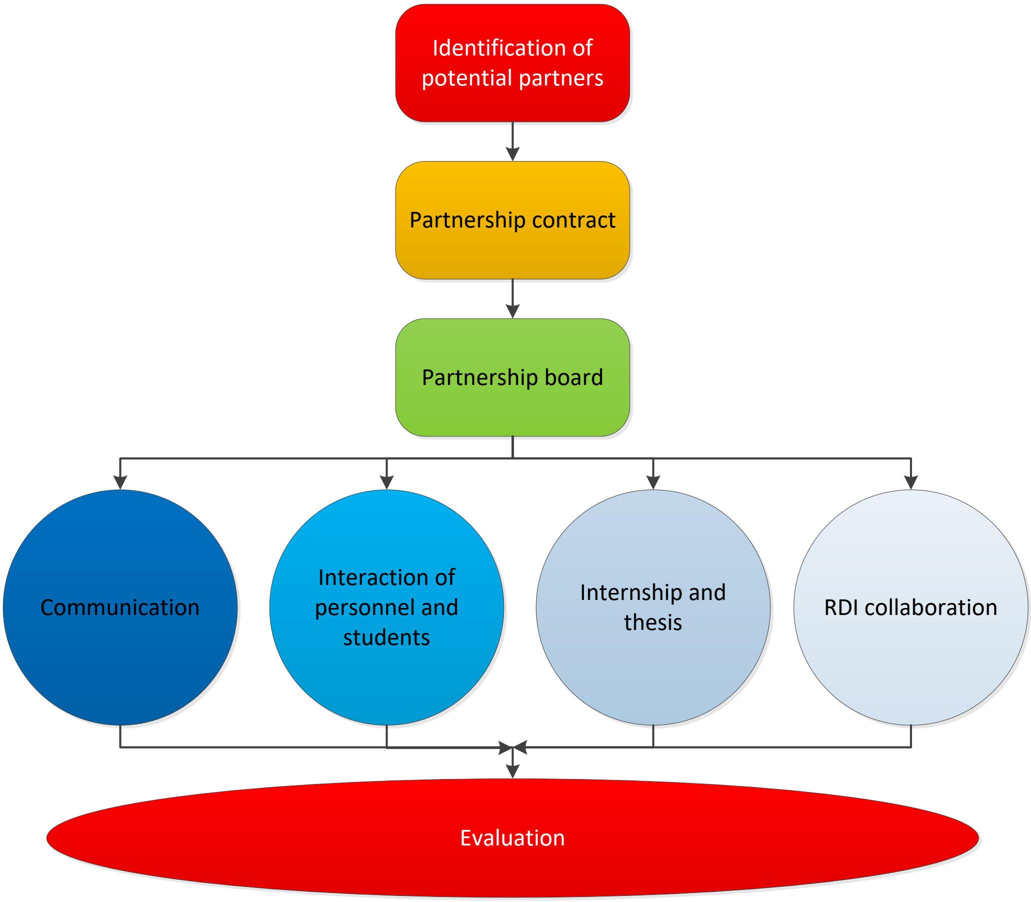

FIGURE 4 Partnership process model

Partnership identification is continuously done by the university employees who are interested in collaboration with partners. At the same time, the existing partners may spread good results of the partnership to their networks and other enterprises may become interested in the partnership with the university. The preliminary partner work is initiated with the potential partner by the responsible university manager. The university has a formal template for the partnership contract. This template is modified to satisfy both parties so that it defines the main objectives for the partnership and the essential actions for achieving them. The significant parts of the contract are the confidentiality agreement, ownership rights and rights to use the material produced in the partnership as well as the agreements of costs, the partnership board and the cancellation of the contract. (*Leino and Laine 2014*)

The partnership board has a significant role in partnerships. The board is nominated in the partnership contract but new members may be nominated at any phase of the partnership or the appointed persons may be changed when necessary. The partnership board meets a couple of times per year and every time all the main actions and their status are evaluated. All the new subjects like new theses, new development projects and adaptive work placements are brought to the board meetings and the board decides which of them will be started. Also the results and possible challenges of the actions are considered by the board. The partnership board coordinates the bigger picture of the collaboration by planning:

- Communication
- Interaction of personnel and students
- Work placements and theses
- Research, development and innovation projects (*Leino and Laine 2014*)

Communication between partners is noticed to be one of the key actions in partnerships. Without proper and systematic communication, the planned actions will not work as anticipated. Communication between partners and external networks is also important especially when results and achievements should be presented or when new collaborative projects are beginning. Communication is set as one of the main subjects on the partnership board meeting agenda. Consequently, all communicative issues will be discussed and planned when needed. (*Leino and Laine 2014*)

RDI collaboration is one well tried way of creating trust but it also requires trust. Therefore, this thesis indicates that it should be started with small steps in the beginning of the partnership. When the first steps of trust creation are taken, the identification of RDI challenges may be started. The first identification is done by listing the acute development needs of the partner enterprise. The knowledge climate creation starts with the reciprocal visits to the enterprise and to the university so that the experts from both organisations could come to know the operations, knowledge and needs of the partner. Then the development needs are operationalised by transforming them into practical actions like research projects or technology knowledge search. Both the identified needs and the practical actions are prioritised according to the importance, urgency and available research knowledge and resources. (*Leino and Laine 2014*)

The prioritised list of development needs and actions is documented so that it can be used as a checklist during the process. Following this list, the development actions are planned and described in more detail. Some development cases may be very quick in the right hands of accomplished personnel but some cases may need longer time periods and also knowledge from other sources. RDI collaboration consists of different operative actions like theses, student projects and more demanding research projects conducted by university researchers and project engineers. Scheduling of all the actions is a part of the checklist writing. (*Leino and Laine 2014*)

Finding the adequate resources for the RDI actions is clearly one of the challenging parts of the RDI collaboration. Resources are always allocated case-specifically. The partnership contract does not allocate any resources but all the actions are planned case by case with separate budgets and a financing programme. When all the plans have been formulated the actions are carried out according to them. When new challenges are met the project personnel tries to solve them with the help of the enterprise's personnel. Challenges exceeding the scope of the action plan are discussed in the partnership board. Other partnership practicalities worth mentioning are:

- Planning of the practical trainings
- Joint actions like trainings and seminars for the personnel of both organisations
- Recruitment info and company excursions for students
- Personnel work placements

From the universities point of view, the work placements and theses are the two most important outcomes of the partnership. Different kinds of work placement methods and thesis subjects are constantly planned and discussed in the board meetings. (*Leino and Laine 2014*)

Regular review and evaluation of the actions take place usually twice a year. The evaluation is based on the objectives defined on the planning phase but also on the process resources and results. (Lähdeniemi et al. 2012; Malinen et al. 2009; Leino 2009).

The important trust creation between the partners is done with small specific action steps like:

- Expressing curiosity towards real world challenges
- Constant identification of new needs
- Versatile evaluation and prioritisation of the needs
- Systematic verification of competences
- Problem solving based on knowledge and systematic approach
- Collaborative learning

All these steps are covered in the partnership meetings. Typically, all real world problem solving requires diversified knowledge. Therefore, the partnership board should consist of people from various fields of industry, education and research. (*Leino and Laine 2014*)

3.4 Evaluation of the partnership process model

The partnership process model is a constantly developing process. The formative evaluation was used in finding the best practices of the current model because it helps in achieving the goals of the partnership activities (Flagg 1990). In this chapter the evaluation findings of the partnership process are presented and the identified best practices are named (TABLE 1). The evaluation is made according to the hypothesis that the main goal of a partnership is to create practical results.

TABLE 1 Evaluation and best practices of the partnership process (*Leino and Laine 2014*)

Partnership process phase	**Evaluation findings of the phase**	**Best practices identified**
Identification of partners	Active identification, different types of partners, contacts based on partners' recommendations	Openness to all types of partners and partnerships
Partnership contract	Formal and simple general template, partner based details, commitment of senior management	All key actors involved, shared understanding of importance and trust, contact person of the university selected
Partnership board	Role of the contact person is remarkable, all voices are heard, equal partners with equal authority, well documented meetings, all ideas, plans and actions covered	Covers everything but not in detail, future-oriented approach
Collaboration	Several simultaneous actions and communication, the role of a student is emphasized, only part of the partners want to include RDI collaboration	Type of collaboration based on needs, opportunities for students to participate in different types of tasks, step by step creation of trust based on collaboration, time scales and actions agreed, concrete results
Evaluation	Continuous, informal, learning centered, UAS actively asking for feedback, made by the board, a lot of learning outcomes from university processes	Evaluation on agenda in all meetings, reporting results into the university metric systems for maximum benefits

Continuous evaluation is done in all board meetings, not as a separate action. This ensures constant feedback and fresh thoughts, because the evaluation is done when actions are still in the short-term memory. The contact person of the university collects feedback from the students and teachers and the contact person of the partner organisation from their organisation. The evaluation focuses on

- Quality of the planning
- Quality of the actions
- Quality of the process and resources
- Achievements reflected on goals, amount and quality
- Management of actions

- Partnership based communication and publications
- Interactions in the partnership
- Scope of the partnership

The board meetings are documented and the documents or the relevant parts of them are distributed to all people involved. (*Leino and Laine 2014*)

3.5 Analysis of the partnership development process

In this research the partnership process between HEIs and local enterprises was described, modelled and evaluated. According to the findings, it is important for partners to understand the importance of trust and creating trust, to make clear goals for the partnership, to agree on operational actions, to perceive time scales, and to create concrete results with mutual benefits for the university and industry. The partnership process is described as linear. However, when the board is nominated and parallel actions start, it may not look as simple as the description. According to the research, all partnerships are different, but similar process phases and elements can be found in each of them. Identifying the related and complementary knowledge areas of the partners is a very important step leading to the next level of the partnership. (*Leino and Laine 2014*)

In this research, the creation of trust and knowledge climate is considered as one of the important factors of a successful partnership. This research shows that both knowledge based trust and identification based trust are usual in this kind of partnerships between a university and industry. It also indicates that the sooner the transition from knowledge-based trust to identification-based trust happens, the sooner the partnership gets on a more detailed level of collaboration. Identification based trust makes it possible for the partner to deeply know the processes and products as well as their problems. Consequently, the results of the partnership may be remarkable. (*Leino and Laine 2014*)

A good sign that shows that the network is actually developing is that its members create new practices together. In partnerships this should happen in similar ways. In the studied cases this seems to be true. Partnerships based on organisation specific contracts seem to develop into their own directions. The coordination of the actions is a demanding task, and therefore the quality of the partnership and its development seems to be personified into the coordinator. So it is important to find very committed people from the university side to coordinate the partnerships. Otherwise it is not possible to increase the number of partnerships. Partnerships help to develop the competences needed in partner organisations. Both the university personnel, the students and the personnel of the partner firm seem to learn a lot in the collaborative actions taken in partnerships. A university coordinator convinced:

> “Nowadays all my new competences are based on needs of the partners.”

The role of students is also emphasised in the partnerships. Several students have participated in different roles. The same students can also have several different roles in the same partnership during the years. The students give the university a lot of feedback that can be used in developing the processes. They seem to be very satisfied with the learning outcomes which they have attained in different projects. Also the adaptive work placement generates a lot of positive feedback. The students especially praise the wide range of working experiences. (*Leino and Laine 2014*)

Partner organisations are satisfied with the amount and type of actions, systematic problem solving approach, research knowledge based on their own process data, and the documentation of the results. As a partner organisation representative stated in a board meeting:

> "It is easy to make decisions now because we have true knowledge based on measured data."

The partnerships have helped the partners to solve several problems, create new products and services and make investment decisions based on achieved knowledge. Partnerships create research-based knowledge to support innovation processes in the industry, foster new innovation creation and recognise new opportunities for future collaboration. (*Leino and Laine 2014*)

This research of partnerships has implications for both theory and practice. The created model can be utilised in the management of partnerships and in the collaborative creation of innovations between higher education and industry. The modelling is a generalisation since it is a simplified description of reality and the research tried to capture the most essential parts of the phenomenon. The research was found to have several practical implications. The results can be generalised into similar environments and organisations, yet should be used with care because the initial conditions also affect the results that can be achieved. One essential question for the future was set to be: how to develop the partnership process so that the university gets to actively set their own goals already in the beginning of the process. It would be important to ensure actions which create significant results also for the university. This observation was taken into consideration later on technology knowledge transfer development and its solutions added remarkable value to the quadruple model for collaborative technology research activities between higher education institutions and industry. (*Leino and Laine 2014*)

4 Different modes of technology research

In this thesis the applied technology research process and its factors at the universities of applied sciences have been studied. The important basis for this research has been the applied technology research cases, which were conducted from year 2008 to year 2016 in the fields of automation and well-being enhancing technologies as well as in developing the partnerships and technology knowledge transfer. The actions and procedures performed in these cases have indicated both the big picture and the little details, which were then used in the modelling of the process. This chapter introduces two modes of applied technology research in order to prove the versatility and multidimensionality of the research work.

The technology research done at universities of applied sciences stand out in the field of university research because of its ambitions to solve evident, real world challenges. The intent is not to understate the meaning of basic research, which has the most significant role in generating new technologies. In this thesis the role of UASs is defined as the technology knowledge interpreter between basic research and enterprises, especially SMEs. The research knowledge and practical skills are combined in order to answer the questions and needs of the enterprises. The meaning is not just to examine how some technology works or how it could be utilised but to find out how it should be used in some specific case. The applied research is a correct term to be used when talking about technology research at universities of applied sciences. The main goal of the research work is to apply new technologies to new cases and to create new applications.

4.1 Technology research in the field of well-being enhancing technologies

As the first mode of applied technology research in this thesis, an example of well-being enhancing technology research is introduced. This example presents a research of applying serious games as assistive technologies for memory impaired older adults. One of the most significant groups of diseases which require the support and intervention of health and social services, are memory disorders. They cause physical, psychological and cognitive challenges, like impairment of observation, attention, working memory, processing speed, dual tasking, coordination and visuospatial conceptualisation (Spector et al. 2003; de Oliveira Assis et al. 2010; Fairchild and Scogin 2010; Kueider et al. 2012). Memory disorders become more and more common as the people age. This means that disabilities progress and the need for continuous assistant is increasing (Peretz et al. 2011; Kueider et al. 2012). Carefully prescribed medication, timely support, physical activity and individualised rehabilitation are proved to be practical ways of slowing down the progress of a memory disease (Rosenberg et al. 2011; Bottino et al. 2005; Giordano et al. 2010; de Oliveira Assis et al. 2010; Fairchild and Scogin 2010; McCough et al. 2011; Kueider et al. 2012). (*Merilampi et al. 2014*)

People in Europe are aging. This has led to the development of new, innovative care and rehabilitation methods, which aim at client's independence and selfcare, where the role of specialists is decreasing (Ministry of Social Affairs and Health, 2013; Steel and deWitte, 2011; Rodeschini, 2011; Kueider et al., 2012). Activation in this research is defined as all the proactive actions which enable people to take care of their health challenges. Activation includes participation in decision making concerning one's own health care and in activities that maintain functional fitness and reduce health degradation. (*Merilampi et al. 2014*)

There are many scientific research studies which indicate that people can improve their alertness, dominance, feeling of pleasure and consequently the state of experienced well-being by playing video games (Peretz et al. 2011; Khoo and Cheok 2006; McCough et al. 2011; Nouchi et al. 2012; McCallum 2012). Simple and easy video games seem to be more easily accepted by older adults. The research studies also prove that these games create positive feelings and enjoyment (Sirkka et al. 2012; Koivisto et al. 2013; Mountain and Craig 2012; Kueider et al. 2012; Hwang et al. 2011). In this research, different games aimed at older adults with memory impairment were generated for touch screen mobile devices. The elderly people are more and more familiar with the touch screen based devices. Smartphones and tablet PCs equipped with an accelerator sensor were chosen for this research. The research studies of Fairchild and Scogin (2010), McCough et al. (2011) and Szturm et al. (2011) indicated that older adults experience physical exercise and game playing very positively. Because of these findings a game combining physical movement and cognitive stimuli was generated in this research. The game is called Cat vs mouse (FIGURE 5) and it is based on simple turns of the mobile device. When the device is turned the mouse moves on the display. Every now and then a cheese cube appears on the game platform and the player should move the mouse to eat the cheese cube. Each caught cheese cube gives ten points for the player. After 50 earned points a cat appears to the game trying to catch the mouse. Then the player should try to flee the cat but still chase the cheese. After 100 points another and after 150 points a third cat appears on the screen. If the cat catches the player the game is over. Otherwise, the game ends after the set time. In addition to light physical exercise this game requires simultaneous coordination of hands and brain. (*Merilampi et al. 2014*)

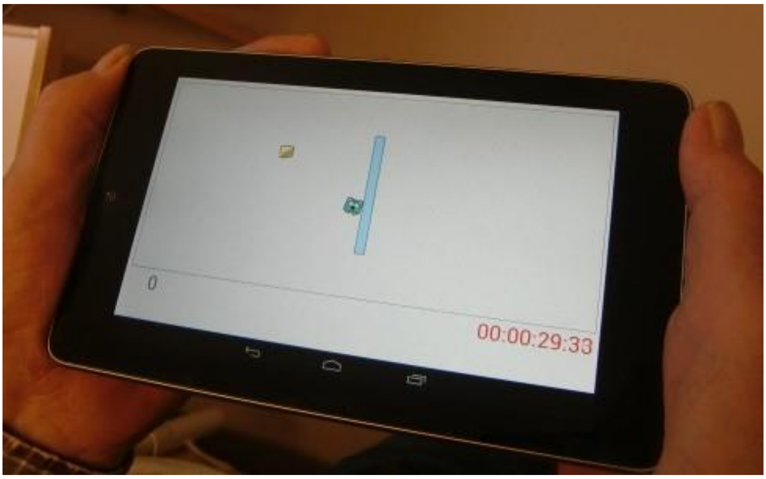

FIGURE 5 Cat vs Mouse game

The other game for this research is based on the traditional Trail Making Test (TMT). Traditionally the Trail Making Test-A is done with pen and paper and it is used for assessing and detecting several types of cognitive impairment (Alaska Department of Administration 2013; Poreh et al. 2012). For this research the test was redesigned as an interactive mobile game. At the beginning of the TMT game (FIGURE 6) the player can choose whether to use numbers or both numbers and letters. Then the amount of characters is chosen. The game starts by showing the characters in disorder on the screen. The player must touch the characters in right order from the lowest to the highest or if there are both numbers and letters from one to A and then to 2 and B etc. The faster the player is the better the score is. If the player touches the wrong character more than twice the game is over. (*Merilampi et al. 2014*)

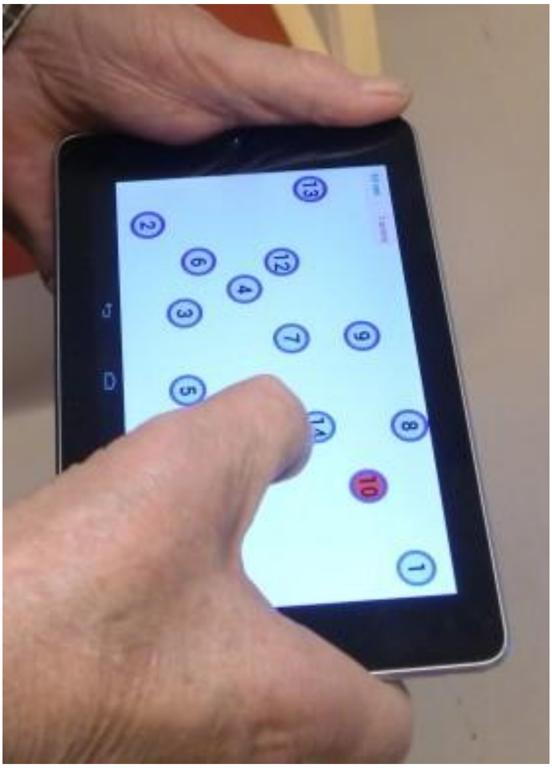

FIGURE 6   Trail Making Test game

Both games were designed to be as simple as possible because of the presumption that the players may not have any technical experience. Because of this the player identification was also automated using the near field communication (NFC) embedded to the devices (NFC Specification (NFCIP-1 (ISO 18092 or ECMA International 2013))). The players' user experiences were collected by semi-structured interviews. The staff also followed the players in action and forwarded their observations for the research group. (*Merilampi et al. 2014*)

The games were used to study the usability of this kind of game technology in self-management, activation and rehabilitation. The target group playing these games consisted of older adults with slight memory impairment. The aim was to determine if the mobile games with cognitively stimulating functions could improve or at least maintain the memory abilities or attentiveness of the target group. The older adults were also interviewed in order to identify their experiences. The experiences were analysed and the results were used to develop the games. (*Merilampi et al. 2014*)

4.1.1   Game trials

Cat vs mouse and TMT games were used in game trials in War Veteran's Nursing Home and Rehab Centre for three months. Male players with an average age of 90 years volunteered to play these two games for five minutes nonstop and twice a day. In addition to the group of players there was also a control group. The games were changed repeatedly every other week so that Cat vs mouse was played on weeks 1, 3, 5 etc. and TMT was played on weeks 2, 4, 6 etc. All the playing data like scores, dates, times and errors was collected to a database and it was carefully analysed. This research focused on recognising and identifying measurable impacts of continuous game playing with these two games to the results of the traditional Trail Making Test results of the target group. At the same time the quality of the player experiences on playing the mobile games as part of the self-activation and cognitive rehabilitation was studied. (*Merilampi et al. 2014*)

4.1.2 Results of the trials

In the three month trial 9 male players played the games almost according to the plan. One player had to end the trial in the middle of the period because of a severe change in his health condition. Another player from the control group was chosen to replace him. The scores combined with the player IDs of each game play were tabulated and the analysed results were presented as figures with regression lines (FIGURE 7).

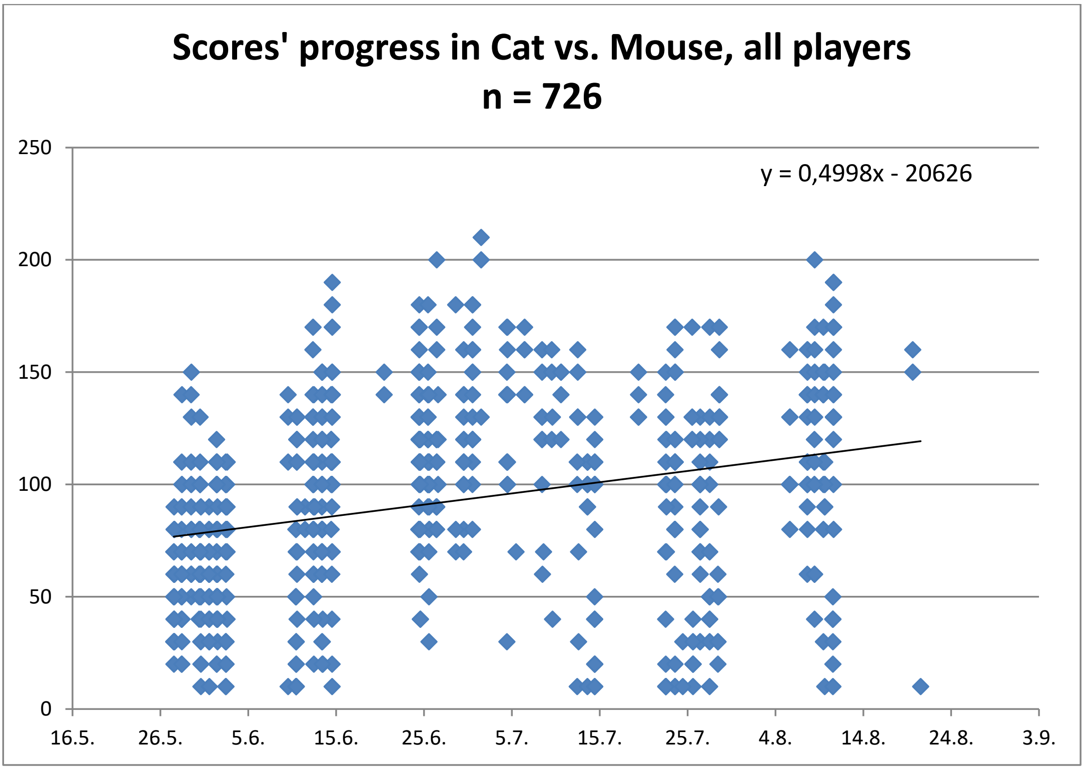

FIGURE 7 Example of the scores' progress figure with the regression line

The scores' progress was analysed both player by player and in a combined way for both of the games, Cat vs mouse and TMT. The analyses indicated that despite the players' advanced age, the three months' period of game playing improved the attention and reaction skills related results. This was the most significant finding of this study. In addition to this the research group noticed that the players were highly motivated and interested due to the constant intensity of playing the games. In the interviews both the players and staff reported similarly that the players with an age of even over 90 years easily learned to use the tablet PC and to play the games. Another interesting finding was that achieving the optimum progress in the games required regular playing. Almost no one of the players succeeded at the higher difficulty levels of the TMT game. The analysis cannot indicate if this finding depends on the lack of playing on higher levels or on the lack of interest in playing on the higher levels because they were too difficult. This question is worth considering and investigating in future studies. One confusing finding was that also the individual player's scores varied even during one day. This raises the need to consider if this fact should be better taken into consideration also in the traditional Trail Making Test. (*Merilampi et al. 2014*)

According to the semi structured interviews the overall feedback from the trial period of game playing was very positive. The players found the games interesting, exciting and entertaining. Also the family members of the players showed high interest in the games and their relatives playing the games. Even if the memory test results did not improve significantly, the players reported remarkable improvements in their activation level, attention skills and overall well-being. (*Merilampi et al. 2014*)

4.1.3 Impacts of the applied technology research in the field of well-being enhancing technologies

This example of applied technology research in the field of well-being enhancing technologies discloses all the four dimensions of beneficiaries in this doctoral thesis. The main beneficiaries are enterprises and their customers, higher education institutes and their employees, students and the society. Health and care enterprises are looking for new methods of caring. The methods should be more cost efficient but at the same time they should focus on more individualised needs of the customers.

In this research case the impacts of applied technology research in the field of well-being enhancing technologies are seen from each beneficiaries' point of view. The War Veteran's Nursing Home and Rehab Centre introduced one of their rehab challenges to the well-being enhancing technologies research group. Their customers are older adults with memory impairment and they should be motivated and activated to do memory rehabilitation independently or semi-independently. The games were designed and implemented for mobile devices in co-operation between the technology researchers and the rehab centre personnel. This work increased the researchers' knowledge of memory impairment rehabilitation methods and at the same time they studied how to design mobile applications for this specific group of older adults. The three months' trial gave promising results for both the researchers and the personnel of the rehab centre. It also motivated and activated the players and gave them something to share with their visiting relatives. The results indicated that this kind of light physical and cognitively stimulating games can activate the everyday life of the older adults. Therefore, the games may also have societal impacts. In addition to this, the cases of game developing and test trial are also regularly used in the education of health and care technology, so the students can get the new knowledge and the first hand experiences during their studies.

4.2 Technology research leading into an innovation

Another example of different modes of applied technology research in this doctoral thesis describes how the technology research leads into innovations when a recognised need of an enterprise and the practical knowledge of researchers meet. This research case was started through a wider need recognition in an SME manufacturing nails and reinforcements. A more automated system for the measuring of the reinforcement bars (re-bars) was found as an area where the enterprise's and the university researchers' knowledge met in a way that could lead into innovations.

Machine vision technologies were identified to have potential for measuring the re-bars. At the same time, it has become more and more commonly used in automatic processes during the past decade. The accuracy of machine vision cameras is now on a level where complete systems can be built around average priced cameras. Today the different features can be analysed more accurately by machine vision than by human eyes. At the same time, the diversity of analysis software and out of the box tools of the software allows easy application development. Because of these reasons it was possible to take the measurements of re-bar's geometrical characteristics based on machine vision technologies. (*Valo et al. 2013*)

The re-bars used in concrete building are strictly standardised. A certified third party makes sure that the standards are followed by inspecting samples taken from production lines from time to time. Finnish Standard Association's SFS standard SFS-EN ISO 15630-1 states the experimental methods that may be used in measuring concrete steel rods, hanks and threads. In order to fulfil the requirements, set by the standard, the re-bar manufacturers also measure re-bars taken from the production. In re-bar manufacturing the generally used measuring method is to measure a sample from the production with a calliper. If the measurement is done with a calliper, the resolution, repeatability and speed does not reach the required level. If the measurement process is to be sped up and made more precise, it needs to be automated. (SFS-EN ISO 15630-1 2012; *Valo et al. 2013*)

The first research question for this case was: would it be possible to automate the measuring of the re-bar's geometrical characteristics? This started the research and development process. System planning, execution and testing of different versions took for over 18 months. (Leino and Rantapuska 2012; Competitiveness with Research Program 2010; *Valo et al. 2013*)

4.2.1 The research, development and innovation process of the re-bar measuring system

This research required plenty of studies in the field of concrete steel manufacturing. Understanding the requirements of the standard, the traditional measuring methods and the goals for the novel measuring system set the base for the innovation. The research and development process consisted of several research and test cycles and led into a pilot version of the measuring system. This chapter concludes the main steps of the research and introduces the system configuration.

The quality control of the cold rolling manufacturing process of the re-bar is mostly sample based. Samples are taken from the manufacturing line on steady intervals and they are measured with callipers in the measuring laboratory. The most important geometrical characteristic to be measured in a cold rolled re-bar is the height of the rib, because the height changes as the roll wears down. Other measured geometrical characteristics are: the rib angle (the rib's angle with respect to the longitudinal axis of the bar), the distance between the ribs, the rib's longitudinal cross-sectional area, the rib flank inclination and the distance between rib rows (FIGURE 8). From these, the rib height, the distance between the ribs and the distance between rib rows can be measured with callipers, but the rib's longitudinal cross-sectional area, rib angle and rib flank inclination (α) measurements require different type of measurement methods. The accuracy goal for the measuring system was set to 0.05 millimetres. This is the theoretical resolution of callipers, but in practice, measuring something with callipers visually, accurately and repeatedly on the same value is very challenging, which causes significant aberrations to the measurements. (SFS-EN ISO 15630-1 2012; *Valo et al. 2013*)

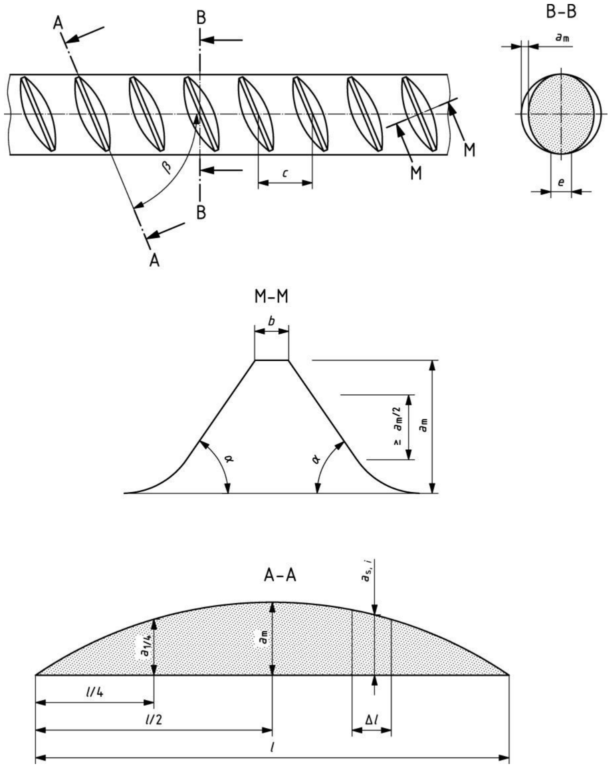

FIGURE 8 Determination of the rib flank inclination (α) and determination of the area of the longitudinal section of the rib (SFS-EN ISO 15630-1 2012)

In planning the automation of the re-bar measurement, the options were either integrating the system directly to the manufacturing line or making a movable measurement system, which would be used in the measurement laboratory. In this first phase of the automation process the goal was set to a fixed measurement laboratory located system. In the first studies machine vision proved out to be the most useful due to its speed, accuracy and versatility. Machine vision system development was started by testing different imaging and lighting methods. The tested methods were: 1. creating a laser line on surface, and measuring the height from the differences of the laser line, 2. stereo imaging system and 3. imaging against a backlight and creating a silhouette image of the object. Studying and testing of these methods indicated that laser line could not be used due to the high reflection of a shiny metal object and because it did not meet the resolution requirements. On stereo imaging, the biggest challenge was the limitations of the technique. Measuring the re-bars' shapes very accurately could not be done with stereo imaging technique, because absolute location information was required for even the smallest changes of the object. Silhouette based imaging was found to be the only option, because it produced sufficiently accurate results. In silhouette imaging the object is imaged against a backlight. This method generates an image where the object is seen as very dark and the background is white. This way, the edges of the object are shown very precisely (FIGURE 9). (Batchelor 2012; Jahr 2006; *Valo et al. 2013*)

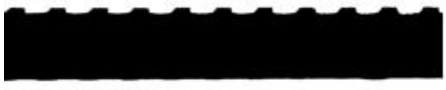

FIGURE 9 Silhouette image of a re-bar

The obvious limitation of silhouette based imaging technique is the two-dimensionality of the images. Taking a silhouette image of a cylinder shaped object will only catch a small portion of the cylinder's topography. To catch the topography of the whole cylinder would require images from an infinite number of different angles. In practice, imaging from an infinite number of angles is impossible, so a certain number of imaging angles would be set to achieve the required resolution. After literature studies and calculations, results showed that the re-bar should be imaged within approximately 1 degree intervals to create sufficiently accurate results. In order to create a realistic image of the re-bar, it should be imaged vertically in the same angle that the rib angles are. This way the silhouette consists of the actual profile of the re-bar, and the ribs will not distort the silhouette. This also limits the imaging so that the object can only be analysed from one side of the re-bar on the silhouette image. Based on these reasons, a stepper motor that takes 0.9 degree steps was chosen for rotating the re-bar rod. (*Valo et al. 2013*)

Due to the requirement of the re-bar's certain angle in relation to the camera in order to get a realistic silhouette image, the different parts of the re-bar are at different distances from the camera (FIGURE 10). This causes problems with traditional machine vision optics, because the area that is the furthest away looks like it is smaller than the same sized area that is closer to the optics. The problem can be fixed within the program, but a better solution is to use telecentric optics. Telecentric optics gather light beams parallel from the field of view. This way, objects that are similar look the same size in the image, even if they are located at different distances from the optics. In practice, telecentric optic's depth of field sets limitations to the distance from which the objects can be imaged without losing the focus of the image. One major limitation of telecentric optics is that the field of view is always smaller than the diameter of the lens. (*Valo et al. 2013*)

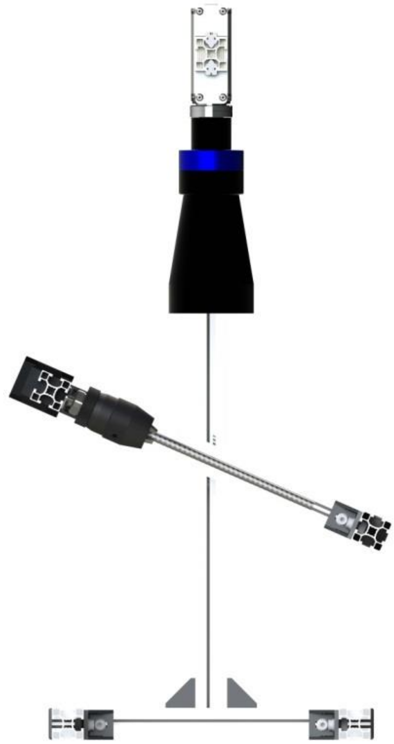

FIGURE 10 Placement of the camera, optics and re-bar in the measuring system

The 0.05 mm resolution goal of the measuring system set a requirement of a minimum of 2000 pixels for image with a diameter of 50 mm. Due to this the camera that was used in the system was a 10 megapixel camera with the resolution of 3840 x 2748 pixels. The chosen camera has a ½ inch sensor, which gives a 56 x 42 mm area of image with the chosen telecentric optics. With these specifications, a pixel size is approximately 0.015 mm. This gives the theoretical resolution of 0.03 mm for the system, which fulfils the requirements. (Spencer and Batchelor 2012; *Valo et al. 2013*)

4.2.2 Solutions

This chapter introduces the solutions for the re-bar measuring system. The system consists of a machine vision camera, telecentric optics attached to the camera, background lighting, a stepper motor for rotating the re-bar and a stand which assembles the whole system (FIGURE 11). The images taken by the system are brought to the computer to be analysed by a machine vision program. The analysing starts with transforming the images into binary images by using thresholding. As a result of the thresholding the re-bar is shown black and the background is white. All of the images taken from different view angles are transformed and stored this way. The image acquisition is as fast as possible, because the images are not analysed yet. After image acquisition, the re-bar can be taken off from the system and the computer will start the analysis. (*Valo et al. 2013*)

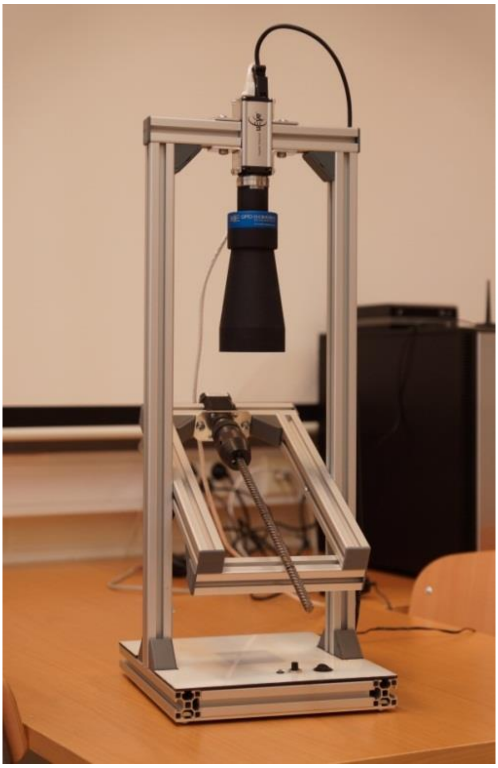

FIGURE 11 Machine vision system for measuring geometrical characteristics of reinforcing bar

The stored binary images are used in analysing the re-bar's movements as it rotates around its axis. With the help of this information the re-bar's rotation axis can be determined. When the axis is known, the silhouette analysis can begin. The silhouette edge is compared to the rotation axis, which is compared to the silhouette image from the other side when the re-bar has turned 180 degrees. When this comparison has been done to all of the images, it can be deduced when the re-bar's ribs are vertical from the camera's point of view. Thus an edge used in a silhouette image can be recognized. From these recognized edge points a 3-dimensional point cloud is calculated trigonometrically. The point cloud is covered with polygons creating an accurate 3D-model of the imaged re-bar (FIGURE 12). (*Valo et al. 2013*)

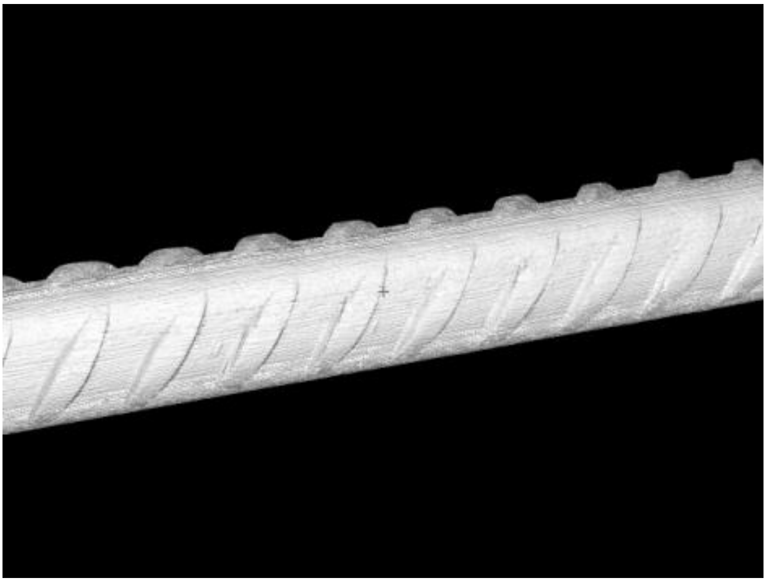

FIGURE 12 3D-model created from silhouette images of a re-bar

The distance between the ribs, the rib height and the rib flank inclination are calculated from the 3D model by first recognizing a plane parallel to the rod in the middle of the ribs. The 3D model cut by the plane is analysed in order to recognise the rib models. From the recognised ribs the rib height and the distance between ribs can be calculated. The calculation of a rib flank inclination works by creating a plane from the rib’s centre point to a 90-degree angle according to the rib. The 3D model cut by the plane is used to recognise the rib’s rise, and from that, the rib’s angle can be calculated. The ridge’s longitudinal cross-sectional area is calculated by taking a cutaway parallel to the rib and comparing it to cutaways on both sides of the rib. When calculating the distances between the rib rows, the information of the longitudinal cross-sectional area is used. The created 3D model can be inspected on the computer screen, and it can be saved for later inspection, with the measurement information. With this feature, the measurer can use the information on the re-bars measured earlier to gain information of the cold-rolling machinery’s wearing and its’ effects to the final product. (*Valo et al. 2013*)

The machine vision system for measuring a re-bar’s geometrical characteristics is a result from long term applied research. This pilot system is the fourth version of the system during its trajectory. The first phase of the system development was the designing and testing of the imaging and lighting methods. Refining these two methods took three different versions of the system. After the so-called hardware phase was completed, a more precise plan for the software and the execution of the plan was made. As a result, a pilot version of this innovation was built up. A wide series of measurement tests is carried out within the system, from which the real accuracy of the system will be known. In the future, the goal is to create a version of the system which can be integrated on the production line. This would make it possible to take real time measurements of re-bars, so that samples are no longer required. (*Valo et al. 2013*)

4.2.3 Impacts of machine vision technology research

The impacts of this kind of recognised needs based applied technology research conducted by the researchers and experts of a HEI can be observed from different angles. From the SME's point of view, the main point was to develop and automate the measuring process but also to assimilate new knowledge and thus create new ideas for manufacturing, too. This research pointed out again how the assimilation of the new knowledge and the success in the exploitation of the new system depends highly on the interest and commitment of the SME representatives. The need recognition made together with the SME key persons highlighted the most interesting development needs which made it easy for the SME representatives to commit to the project. This was the most productive situation for smooth collaboration. In the finalising phase of the project the key SME representative was replaced due to retirement and this caused a slight lack of interest.

From the researchers' and experts' point of view the research, development and innovation work in this kind of applied research project was very educational. The combination of theoretical research and practical engineering increased the technology knowledge and strengthened practical skills. New innovation was based on new technologies or actually on interdisciplinary technology solutions, which also developed the innovative thinking of the researchers and experts. The collaboration with the SME was first quite fluent and when challenges arose the HEI researchers and experts also had to develop their communicative skills.

This research, development and innovation project in the field of automation and machine vision technology was long, multidimensional and challenging. Different parts of the process have been used as case examples in the engineering education. The solution and its development phases have been introduced as machine vision development and engineering examples to engineering students. The experts who worked in this research project have deep understanding and subjective experiences of the development and due to their educational knowledge they can present the processes in a motivational and inspirational manner. This has clearly increased the students' interest. On the other hand, the SME collaboration has been used as a research case in the technology knowledge transfer modelling. It was one of the most multidimensional cases and returned a number of best practices for the modelling.

5 Technology research paving the way for more relevant assimilation in technology knowledge transfer

The earlier chapters introduced the partnership process between HEIs and industry as well as mode examples of various technology research procedures. There are plenty of other procedures and methods in this field of innovation targeting technology research. In Europe, technology transfer offices (TTO) are quite usual at universities. The roles of these TTOs vary a lot across European universities. A TTO may lead the technology transfer process from start to finish or it may only have a supporting role in collaboration (Kuiken and van der Sijde 2011). In Finland this kind of technology transfer offices are not that common. The technology transfer is often seen as a part of a technology research process. A HEI-industry partnership is a platform mode that actively generates technology research processes between HEIs and enterprises.

Different universities and institutions have different ways of technology research related technology transfer. Often the technology transfer process is not precisely planned but the dissemination is conducted case-by-case. This means that today the collaboration between universities and enterprises is much more diversified, open innovation targeted and more strictly based on clear needs. As UASs are nowadays known as competent operators also in the field of research there is an evident need for more efficient research practices and procedures.

Applied technology research in the Finnish universities of applied sciences (UAS) has developed its modes since the early days of universities of applied sciences in the 1990's. The modes of technology research have appeared for example as deep basic research, more applied, solution-seeking research, step-by-step development and student engineering projects. Today the research work in universities of applied sciences has found its place and has a significant role especially as a regional innovation actor.

5.1 The unquestionable need for applicable knowledge

When developing technology for products and manufacturing, technology knowledge creates the base for innovations. This leads to a widely known need for enterprises, having to adopt the newest technology knowledge in order to develop and create new innovations. In the knowledge driven economy this means that there is a growing need for deeper and more productive interactions between higher education based research and industry. (*Laine, Leino and Pulkkinen 2015*)

Laine (2010) states that strategies, incentives and appropriate processes are highly required when aiming at meaningful knowledge exploitation. On the other hand, the higher education institutions should have proficient interaction between the main RDI processes and the knowledge transfer processes. It is important to adopt the fact that in a knowledge based economy, the likelihood of creating new knowledge is higher in application or solution development based collaborations. This kind of knowledge creation processes are carried out through simultaneous actions of knowledge creation, dissemination and utilisation. The need for new, applicable knowledge forces the basic research and applied research to converge or at least to approach each other. Laine also underlines that long-term partnerships with trust, commitment and mutual benefits are found favourable platforms for knowledge creation. (Laine 2010; *Laine, Leino and Pulkkinen 2015*)

Both the universities and the enterprises looking for new knowledge have to consider and identify the adequate ways for collaboration in order to achieve the next level of innovation development. Several studies have noted that traditional, linear knowledge transfer from the universities' basic research to IPR commercialising and licencing etc. has come to its turning point (Perkmann and Walsh 2007; Bradley, Hayter and Link 2013). The universities must create their own ways of technology transfer and the enterprises should attend to this work in order to adequately benefit from it in technology development. Kautonen et al. (2015) emphasized the role of the universities' own, individually and regionally focused knowledge transfer models. (Bradley, Hayter and Link 2013)

Collaboration matters, but new ways of collaboration have to be explored. The collaboration between HEIs and Industry could be developed towards a more operative and goal focused manner. The change in enterprise behaviour is indisputable. When earlier they were curious and participated in research projects in order to see if the research had something to offer them, today they want to define their own needs and goals for the research, with no time allocated for open-ended processes. Concerning the more specified targets of the enterprises, one assumption in this doctoral thesis is that HEIs should also set their own targets and initially introduce them for the enterprises. This way some confusion and mistakes could be avoided. (*Laine, Leino and Pulkkinen 2015*)

5.2 Absorptive capacity and disseminative capacity

Innovation is seen as one of the main themes in developing the technology knowledge transfer processes. The goal of the development work is to achieve a higher level of technology transfer, where the actions are not just aimed at searching and finding technology knowledge and interpreting and enriching it for the enterprises' purposes but to use this new knowledge in creating targeted open innovations. The initial assumption has been that in addition to the applied technology research competences of the engineering educators they also have the professional ability to act as technology knowledge senders as illustrated in FIGURE 3, Winberg's (2008) figure of Identity shifts in the process of acquiring pedagogical content knowledge. (*Laine, Leino and Lähdeniemi 2016; Leino 2017*)

In addition to the needs of new models for technology knowledge transfer, a widely discussed subject by scholars is the enterprises' ability to exploit and use new knowledge. In order to access certain external knowledge productively enterprises should have a certain level of internal resources and absorptive capacity. Absorptive capacity is seen as a threshold factor in the effectiveness of university-industry interaction. Cohen and Levinthal (1990) and Nieto and Quevedo (2005) stated two factors affecting an enterprise's incentives to learning and ability to apply new knowledge. These factors are the quantity of knowledge and the difficulty of learning. Absorptive capacity is defined as the ability of an enterprise to recognize the value of new, external information, assimilate it, and apply it to commercial ends (Cohen and Levinthal 1990). The knowledge characteristics are used in the determination of learning. The complexity of the knowledge and its suitability for the enterprise's absorptive capacity are important. The balance between the level of new knowledge and the absorptive capacity of an enterprise has a positive impact on the innovative efforts of the enterprise (Nieto and Quevedo 2005). (*Leino, Katajisto and Laine 2015*)

When considering the absorptive capacity of an enterprise as a key factor of a successful knowledge utilisation also the disseminative capacity of the technology knowledge sender has an important role. Cohen and Levinthal (1990) explained that efficient knowledge dissemination is dependent on the absorptive capacity of the recipient but demands a collaborative effort too. They suggested that the attitude and behaviour of the knowledge sender have an important role. Knowledge transfer depends highly on the ability of the sender to share the knowledge in a way that the receiver can understand (Minbaeva and Michailova 2004).

The disseminative capacity as the knowledge sender's competence is like the counterpart for absorptive capacity. The disseminative capacity is defined as a capacity of an organization or institute to transform certain knowledge into value for other actors like enterprises with commercial or learning purposes (Kuiken and van der Sijde 2011). Szulanski (1996) argued that disseminative capacity is dependent on both the ability and willingness of knowledge senders to share knowledge. Disseminative capacity can also be seen as a question of the university's ability to understands the needs of enterprises. Kuiken and van der Sijde (2011) listed the topics important for dissemination capacity:

1. Purpose of knowledge transfer
2. Transformation of knowledge
3. Importance of valuable knowledge from a respectable source
4. Issues of network and inter-organisational dynamics

All these topics should be considered from both the enterprise's and the university's point of view when designing technology knowledge transfer. (Kuiken and van der Sijde 2011)

5.3 Technology transfer modelling

In Finland the universities have a wide range of experts in their personnel. The HEIs have experts of different technologies combined with technology knowledge transfer competences together with education ranging from Bachelor of Science to Doctoral degrees. UAS expert educators and researchers also know the local enterprises and their fields of business. This combination sets the base for collaboration but a practical operational model is still required. This thesis describes the multidimensional process model for technology knowledge transfer which has been created, piloted and tested with local SMEs. The model is used when the UAS scan, search and interpret international technology knowledge for SMEs. The main focus of the modelling has been in actions and collaboration executed by university and enterprise personnel. Furthermore, the students have a significant role in all of the operational actions. (*Laine, Leino and Pulkkinen 2015*)

UASs have developed their research, development and innovation activities since the beginning of UAS era. This thesis concentrates on the modelling and piloting of the procedures especially suitable for the applied technology research and technology knowledge transfer between HEIs and small and medium sized enterprises (SMEs) but also on the procedures of integrating the applied research into the engineering education.

This technology transfer process model has been developed in two main phases. Both phases have been based on true innovation collaboration and processes between HEIs and Industry. In the first phase the processes were executed with ten enterprises in ten technology research, development and innovation cases. Most of the ten cases had several participating enterprises and the majority of the enterprises were SMEs. As the result of the first phase the initial “process model for international technology transfer” as well as the wider and more open “innovation targeted participatory research process” were created. The first phase was divided into two parts. First, the initial process model for international technology transfer was developed with six enterprises in three cases concerning new welding technologies, light metal structures and environmental technologies influencing production technologies. Then, the initial model was piloted and developed with four enterprises in seven cases concerning specific machine vision technologies in production and quality control. As a result of modelling this part the innovation targeted participatory research process was created. (*Laine, Leino and Pulkkinen 2015*)

The second phase of the model development was executed in collaboration with two other universities of applied sciences. It was important to bring other UASs to pilot the technology knowledge transfer model, so that the model could be developed into a more general mode while introducing and spreading the model to other UASs. In this phase altogether 16 SMEs participated in the technology knowledge transfer process and brought their needs and challenges into the shared process. With these enterprises 25 different technology RDI cases were put into practise. Most of the enterprises participated in more than one case. Thus their similar experiences and, on the other hand, the different aspects of the cases gave important information concerning the modelling. As a result of this second phase the innovation oriented model for technology transfer was created. (*Leino, Katajisto and Laine 2015*)

In both of the phases the modelling was based on real, implemented cases. In addition to the modelling of the cases the new steps of the cases were also piloted in the following cases and thus the models could be improved during the processes. The essential elements of the models were identified through case comparisons and best practice identification. Finally, the models were simplified and generalised in order to create process models that suit most of the cases. (*Laine, Leino and Pulkkinen 2015*)

5.3.1 The role of HEIs and SMEs in technology knowledge transfer

One of the main goals of this thesis is to describe how systematic technology knowledge transfer based on the recognised needs of the enterprises will foster the targeted open innovations. The technology transfer development, modelling and piloting are presented in this thesis. A key issue in the long term success of a technology enterprise is innovation creation. Innovations should be targeted at least towards the technological development of new products, the manufacturing processes and the adoption of new business models. This means that new technological knowledge should be continuously searched and chosen. Enterprises, particularly SMEs, are known to lack resources for searching new technologies and technological solutions for their purposes. Consequently, the SMEs would benefit the most from independent experts acting as drivers, which assist them to collect complex and fragmented pieces of latest technology knowledge and to transfer it into useful knowledge for the development of production and business activities. Enterprises may also use a considerable amount of resources in order to find out how their processes could be developed or e.g. which technology could be the right choice for the new or improved product line. A specialised expert could be just the missing factor, who has the knowledge needed for the information retrieval, technology interpretation and decision making. For this purpose the enterprises should know or recognise the suitable experts in the scope of their operations. (*Laine, Leino and Pulkkinen 2015*)

In this research SMEs were chosen as target organisations just because they usually do not have enough resources or background knowledge to search and utilise the latest technology information. Then, as a solution for this, the university experts have multidisciplinary, versatile expertise and at the same time the technology, research and pedagogy competences to filter and interpret the technology knowledge in ways that the SME representatives may utilise in their work. In other words, university experts' disseminative capacity is widely exploited. (*Leino, Katajisto and Laine 2015*)

The international technology knowledge transfer process model was created so that it consists of all the necessary steps for searching the latest international technology knowledge as well as interpreting and disseminating it so that the enterprises can benefit from it. The model enables the systematic utilisation of the knowledge searching competences and international network connections of the university for the needs of the enterprises. The targets for the technology knowledge search are recognised in the enterprises. This way the enterprises may benefit from the knowledge as straightforwardly as possible. All the searched knowledge is disseminated in order to answer the specific questions coming from the enterprises. (*Laine, Leino and Pulkkinen 2015*)

5.3.2 The initial technology knowledge transfer process model

The first technology knowledge transfer process model was developed through tests and pilots of different phases and steps more than five years ago. In the early stages of the development, the process was described as a draft with five basic steps:

1. Recognition of needs
2. Plan for knowledge search
3. Initial cycle of knowledge search
4. Search of detailed knowledge
5. Evaluation of knowledge transfer

The first technology knowledge transfer project was executed according to the initial draft with six SMEs. It concentrated on international technology knowledge at European region. All the actions on every step were carefully documented and the best practices were detected. By developing the draft by means of detailed results from the tests and pilots the final version of the first model was constructed. The next figure (FIGURE 13) presents the main steps and phases of this initial model and the steps will be further explained in the next chapters. In FIGURE 13, the steps are presented in vertical direction and the actions of each step on a horizontal plane. (*Laine, Leino and Pulkkinen 2015*)

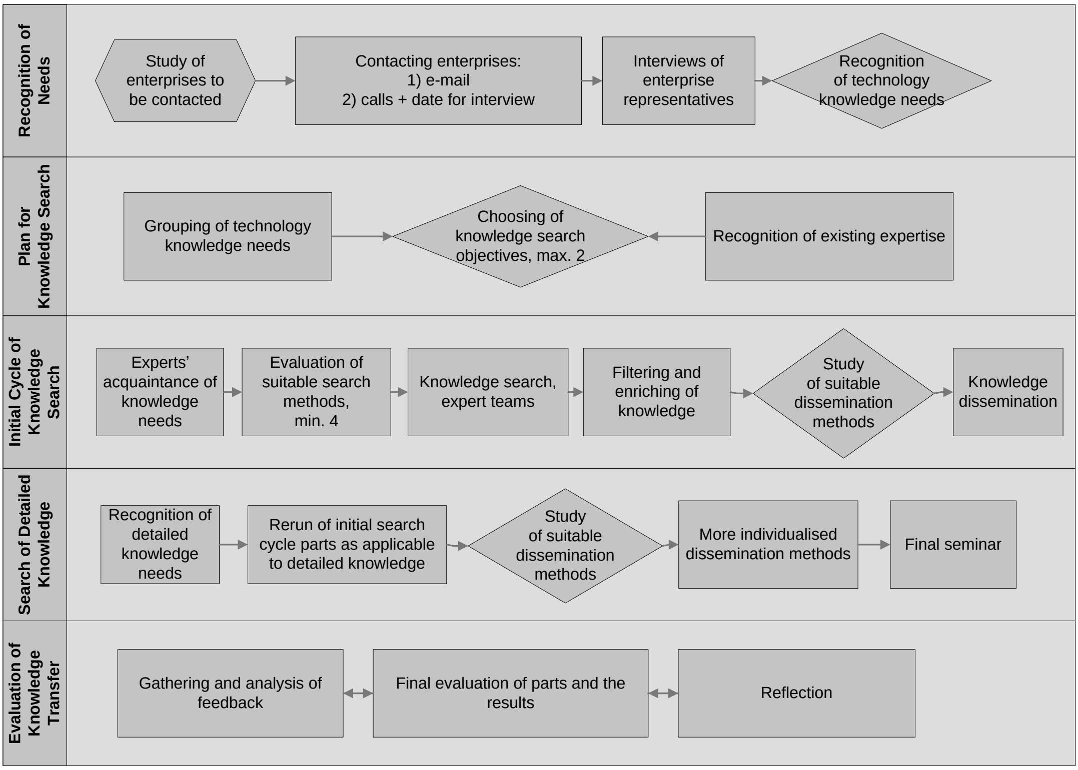

FIGURE 13 The initial process model of international technology transfer (*Laine, Leino and Pulkkinen 2015*)

Recognition of needs

The first step of the model, recognition of needs, includes all the preliminary work that is done in order to define the main technology needs for the knowledge transfer. The recognition of needs begins with the evaluation of the enterprises. Initially, it is essential to specify the field of industry, the size and the geographical location of the enterprises accepted in the project. The evaluation reveals the potential enterprises, which are then contacted by email and afterward by phone with explanations of the aim and operational methods of the technology knowledge transfer process. (*Laine, Leino and Pulkkinen 2015*)

The enterprises with the interest in participating in the knowledge transfer project are interviewed. The properly prepared interviews exploit a qualitative research approach, which offers a possibility for the technology knowledge experts to pose suggestive questions for the enterprises and the enterprise representatives get true opportunities to describe their problems and knowledge needs. It is important to write down the main subjects of the discussions, and also send the memo with the preliminary roadmap for the enterprise to be accepted. The preliminary roadmap has to be made considering the big picture of the knowledge search and technology knowledge transfer, but also, in a careful manner, with the wishes expressed in the interviews in mind. After the interviews of the interested enterprises, the expressed knowledge needs will be analysed. (*Laine, Leino and Pulkkinen 2015*)

Plan for knowledge search

The second step of the model is all about defining the plan for knowledge search. First the recognised technology knowledge needs are grouped into a few groups under a main objective. The amount of different objectives must be carefully considered because the more there are objectives, the more wide-ranging the knowledge search will be. Also, the more there are objectives, the more experts should be involved, which will certainly increase the need for financial resources. Piloted knowledge searches indicated that with two interrelated main objectives, a team of four to six experts can keep the activities straightforward. (*Laine, Leino and Pulkkinen 2015*)

The process of choosing the main technology knowledge search objectives is very much affected by the expertise of the researchers and the university teaching staff. The recognition of existing expertise and recruitment of these experts into the project is the absolute key element of the project plan feasibility. When the technology knowledge needs of the enterprises, found in the need recognition process, meet the existing expertise, the knowledge search plan can be made with good chances of success. (*Laine, Leino and Pulkkinen 2015*)

Initial cycle of knowledge search

The first modelled technology knowledge transfer process consists of two cycles of knowledge search. The first, Initial Cycle of Knowledge Search is wide-ranging and focuses on new innovations, technological changes as well as changes in standards and regulations and on suitable sources of knowledge, like research publications, conferences, events and seminars. Then on the second cycle, the focus is on deeper and more specific cases which have been composed of the first cycle's subjects. On both cycles the knowledge search is done by several simultaneous actions. (*Laine, Leino and Pulkkinen 2015*)

The knowledge search is carried out by expert teams, which can be seen as small knowledge clusters like Carayannis and Campbell (2009; 2012) defined. These teams work by means of their existing national and international networks and also create new contacts to universities, research centres and their company networks. The productive knowledge search is always based on focused dialogue between experts and company representatives. It ensures that the most potential knowledge sources and knowledge search methods are utilized. The plan for knowledge search must be updated regularly by testing several different methods in communication and knowledge transfer. The knowledge search teams aim at versatile dissemination in order to ensure that different kinds of learners may adopt the knowledge. (*Laine, Leino and Pulkkinen 2015*)

In order to guarantee the most efficient start for the work the experts get carefully acquainted with the technology knowledge needs, based on which they choose the search methods for the job. There are two important best practices identified for the expert teams. First, each team should have a nominated person who is responsible for that certain knowledge search and takes care of the team work like collecting of all the searched knowledge together. Secondly, at least part of the team members should also participate in more than one team. Teams with partly common members seem to communicate more fluently and thus avoid overlapping work, especially with objectives close to each other. (*Laine, Leino and Pulkkinen 2015*)

Although the knowledge search is important on this cycle, it is even more important to efficiently filter the relevant knowledge out of all the retrieved knowledge. This is done by the experts based on the questions and knowledge needs stated by the enterprises. The identification of relevant knowledge is performed simultaneously with knowledge filtering and interpreting, so that the company representatives may assimilate the knowledge as easily and straightforwardly as possible. The interpreting is both linguistic and, most importantly, technological, content-related, making the technological novelties more intelligible. When the knowledge and answers have been retrieved, filtered, and examined, the dissemination methods are decided on in order to disseminate the knowledge to the collaborative enterprises. The experts choose the dissemination methods case-by-case by considering the absorptive capacity of the attending enterprises. (*Laine, Leino and Pulkkinen 2015*)

Search of detailed knowledge

The second knowledge search cycle is implemented similarly with the initial cycle of knowledge search, only now the focus is on specific, detailed needs and individual international knowledge sources identified during the initial cycle. The specific needs are recognised in discussions with the enterprise representatives and they have mostly emerged from the first knowledge search. On this second cycle, it is even more important than before to visit the knowledge sources in order to have the chance to ask detailed questions and perceive tacit knowledge that is otherwise difficult to achieve. (*Laine, Leino and Pulkkinen 2015*)

Evaluation of knowledge transfer

As the qualitative research method defines, the evaluation of this kind of a technology knowledge transfer process is very important since it increases and refines the skills of the participants as all counterparts give feedback on the implementation of the project. In the technology transfer process feedback from the enterprises is collected with the university's post project evaluation form. In the feedback form the project's goals are defined for the respondents so that they can structure their opinions on the project outcome based on the initial goals. They are also asked which kind of benefits they have identified and whether they are willing to continue collaboration with the university. The respondents also have an opportunity for open commenting in providing feedback. (Fossey et al. 2002; *Laine, Leino and Pulkkinen 2015*)

The evaluation carried out by the technology knowledge transfer implementers is a wider set of evaluation from different view angles. The aim of the reflection is to observe the following things in order to identify, what was learned and experienced during the knowledge transfer process:

1. Functionality of the knowledge search objectives and activities
2. Success of the knowledge search and dissemination work
3. Success of expert team work
4. Suitability of the expert work methods
5. Success parts of the process
6. Improvement needs
7. Learning outcomes and desires to proceed

A thorough reflection gives the implementers a chance to develop themselves and the technology knowledge transfer activities of the organisation. (*Laine, Leino and Pulkkinen 2015*)

5.3.3 Innovation targeted participatory research process

In this innovation-seeking world, it is one thing to accomplish technology knowledge transfer based on needs and challenges of enterprises but a completely different thing to create targeted open innovations based on the new technology knowledge. That would demand deeper collaboration and shared research interests between enterprises and universities. The theories of open innovation define that open innovation gives more opportunities for enterprises than closed innovation (Gassmann and Enkel 2004; Huizingh 2011; Enkel, Gassmann and Chesbrough 2009). In practice, open innovation may give the enterprise too many opportunities. Often enterprises seeking new possibilities through open innovation processes may overreact and try to cover too many challenges at one time. When the university-enterprise collaboration is based on mutual trust the constructive dialogues may lead to targeted open innovations. The technology knowledge transfer processes, which were defined earlier, have started versatile dialogues with the university's partner enterprises. These dialogues and targeted open innovation processes following them have been modelled as Innovation targeted participatory research process presented in FIGURE 14. (*Laine, Leino and Pulkkinen 2015*)

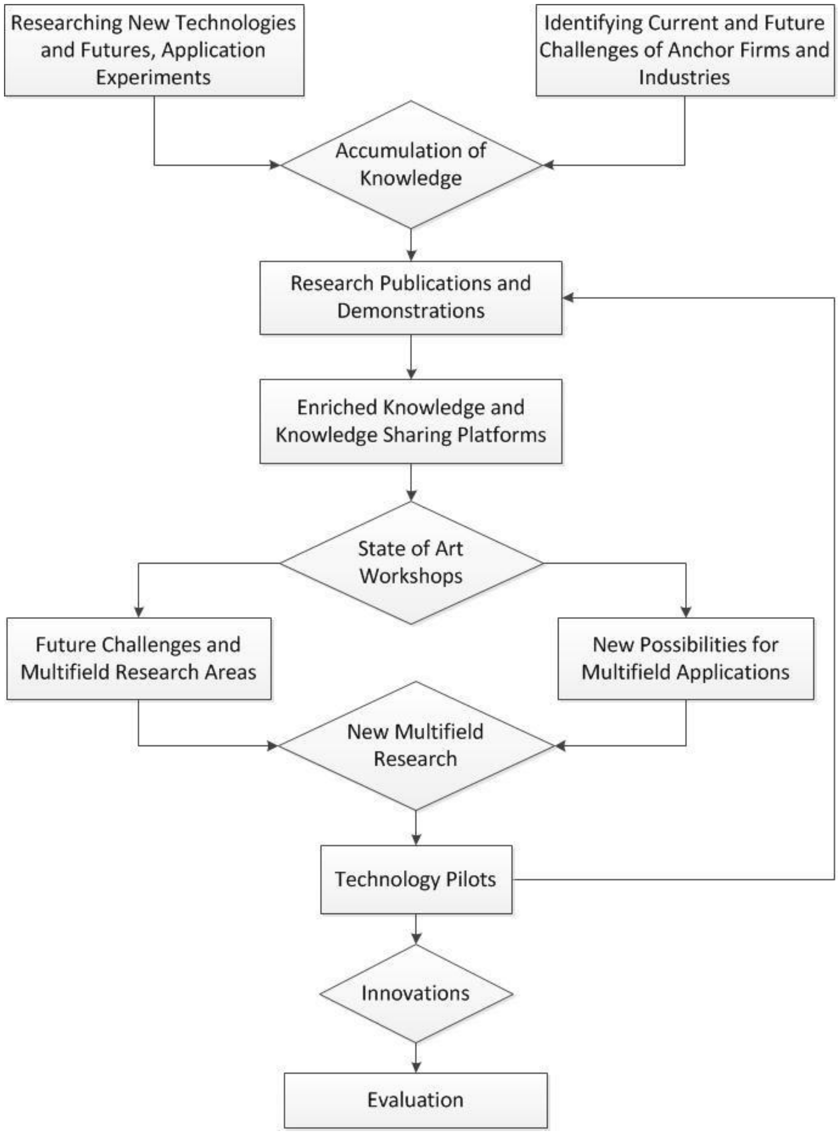

FIGURE 14 Innovation targeted participatory research process (*Laine, Leino and Pulkkinen 2015*)

The aim of the innovation targeted participatory research process is to create new targeted open innovations within the university-enterprise collaboration. The base of this process is in the actions of the initial technology knowledge transfer process, of which the main outcomes are the results of researching new technologies and futures and also the application experiments made based on the research. If the initial technology transfer process is executed completely, the challenges of the anchor firms and industry have already been identified. However, if the technology transfer process has been incomplete or just a background process for the innovation targeted participatory research process, the challenges and needs of the enterprises must be identified. The anchor firms in this context mean, for example, the partnership enterprises with trustful relations with the university (*Laine, Leino and Pulkkinen 2015*; *Leino and Laine 2014*).

The accumulation of knowledge is carried out based on the new technology knowledge and needs of the enterprises. At this stage different technology demonstrations but also research publications are implemented and written based on new knowledge and the refining of it. The demonstrations and publications are then shared on various sharing platforms and presented to the participating enterprises but also more widely to other HEIs and enterprises. In order to ensure that the enterprises identify the possible collaboration opportunities the most important results of the accumulation are presented combined with technology demonstrations in the state of the art workshops. The eventual goal of these workshops is to find and name the most potential innovation targets for the collaborative research. The workshops intend to drive the enterprises to participate more intensely and to bring their own ideas to the participatory research process. In addition to this, the workshops can also expose future research topics beyond the subject. Targeted research subjects and application needs are identified in this process and they lead to more outlined research and further to clearly targeted open innovations. (*Laine, Leino and Pulkkinen 2015*)

The case evaluation of the pilot project proved that in the targeted open innovation processes of universities, the tight participation of the client enterprise is indispensable. The cases seem to have consistently successful results when the enterprises bring their contribution to the process. The innovation targeting participatory research process model has been enhanced according to the following cases. (*Laine, Leino and Pulkkinen 2015*)

5.3.4 Development of the technology knowledge transfer model

The second phase of the technology knowledge transfer model development was conducted between three higher education institutes and 16 enterprises with 25 cases. In this phase the research approach was more extensive as a wide-ranging group of experts coming from three universities worked together within technology knowledge transfer. One of the goals for this phase was to develop, pilot and model knowledge transfer actions for this kind of collaborative process. By developing technology transfer from the different aspects of three universities the functionality and general usability could better be confirmed. After this phase the model can be embedded to the knowledge transfer actions of these universities and it may also be adapted and applied by other universities. (*Leino, Katajisto and Laine 2015*)

This phase had two kinds of goals; the goals to be achieved during the research project and the goals to be achieved by the research results after the project. In the long run a practical technology transfer process model improves technology knowledge of the universities and SMEs as well as accelerates their operational preconditions. It also improves the ability of SMEs to exploit local universities in knowledge and competence development. Furthermore, while the university experts work as technology knowledge searchers, filterers and distributors for the SMEs, they also strengthen their own knowledge. This has positive impacts on the university education leading to up-to-date professional skills of the graduating students. This phase of model development also proved that technology knowledge transfer strengthens the dialogue between university experts and SMEs. From a wider viewpoint this kind of an international technology transfer focused project also serves the internationalisation of the universities, its region and the SMEs. (*Leino, Katajisto and Laine 2015*)

The main goals to be achieved during this phase were:

1. To develop a technology knowledge transfer model that is suitable especially for the UASs and embedding it to the participating universities

2. To increase the knowledge competences of the universities and SMEs and thus develop the searching and controlling of international technology knowledge

3. To create a multiregional model for wide-ranging university experts' co-operation. The goal of the model is to answer the technology knowledge needs of SMEs as comprehensively as possible.

In this phase the research work concentrated in case studies, in which the best practises were identified. The cross sectional study was based on 14 cases and their 11 subcases. (*Leino, Katajisto and Laine 2015*)

In this second phase the action steps of the initial technology knowledge transfer model were developed to better respond to the cross-cutting technology transfer carried out in collaboration with several higher education institutions. The basic steps are quite similar to the initial ones but there are many generalisations and on the other hand several correctives, which make it easier to follow the model in different cases and environments. The model of this second phase follows the procedures of design science research more precisely. Both general knowledge needs and specific questions concerning the possibilities of certain technology applications were identified already during the need recognition phase. The enterprise interviews, cases based on the identified needs and the recognised knowledge sources composed the research plan. In this phase the main topics for the case studies were automation, bioenergy and food processing technology. All the cases under these topics are combinations of similar knowledge needs recognised in different enterprises. (*Leino, Katajisto and Laine 2015*)

This phase of the modelling was executed iteratively. The action plan for this phase is shown in FIGURE 15. (*Leino, Katajisto and Laine 2015*)

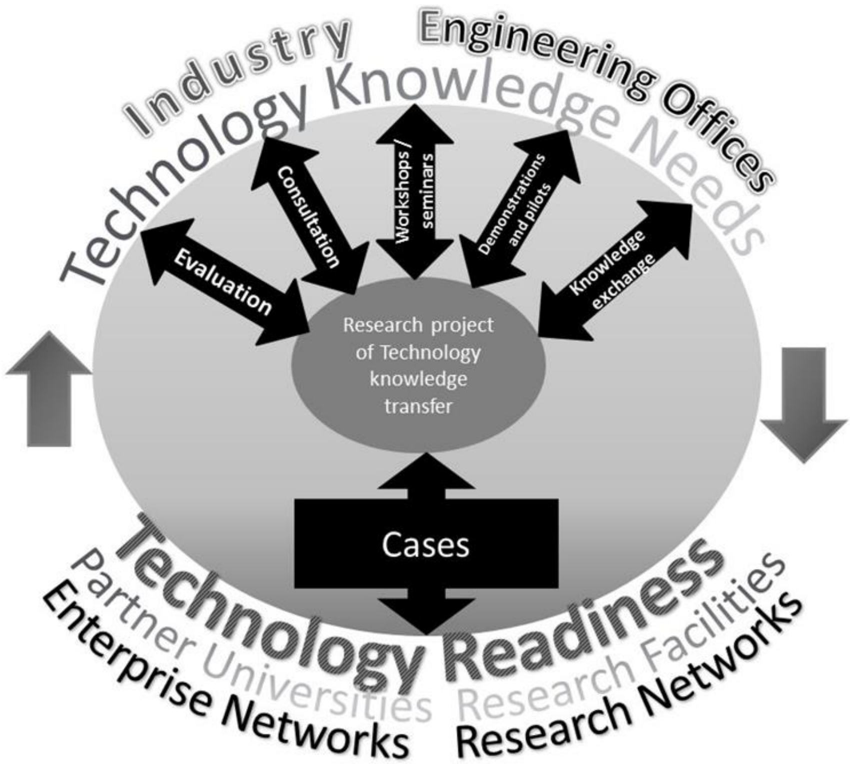

FIGURE 15 Action plan for developing the technology knowledge transfer model (*Leino, Katajisto and Laine 2015*)

The uppermost part of FIGURE 15 illustrates the needs and their sources as the industry and engineering offices. Underneath them the main actions of the knowledge search are presented with the arrows. In the centre of FIGURE 15 there is the technology transfer project, where all the actions took place. The lowest part of the figure illustrates the cases in which the technology readiness was studied with the help of the partner universities, different research facilities as well as enterprise and research networks. The actions presented in the upper and lower parts of the figure were performed iteratively and were interlocked. First the focus is on new innovations, technological changes, standard changes and in events, seminars and conferences. All the time the subjects were redefined by a dialogue between the HEIs and SMEs. With the help of the dialogue and interlocked actions the knowledge search became deeper and the potential information channels and knowledge transfer methods were studied and tested. The new, more specific knowledge needs were sifted from the original needs. The specific knowledge search was iteratively executed in cycles. After each cycle there was a knowledge transfer point for knowledge dissemination and for the identification of more precise knowledge needs. The knowledge search was done by expert teams, which consisted of experts from each of the participating universities. Also in this phase the experts participated in several teams and this way the communication between the teams and subjects was fluent. The following subchapters describe the actions of knowledge search and knowledge dissemination as the most critical parts of this process.

Knowledge search

The technology knowledge search in this phase of model development was mainly carried out by visiting different organisations and events as well as through literature reviews and expert interviews. Good examples of applied research were found at fairs and seminars whereas international conferences, international partner universities and their research institute partners worked as easily approachable sources of the newest technology knowledge. The knowledge search visits of this research phase were made to diverse and moderately goal-oriented destinations. Technology fairs were proven to be effective knowledge sources particularly when the upfront planning of the needs and specific questions was done carefully. At the fairs the application examples have a significant role and the development stages of different technologies can be discovered. (*Leino, Katajisto and Laine 2015*)

More scientific research results can be found in conferences or through literature reviews, but that kind of knowledge often requires more effort in order to be applied in the traditional SME environment. The most useful articles seem to be those with examples of applying the technologies in real environments. They distinctly present how certain technology may be used as well as the challenges of applying it. On the other hand, different device suppliers also publish articles concerning their devices, solutions and the piloting of them. Although these articles give specific information of the device functions they always double as marketing materials, which should be critically considered. (*Leino, Katajisto and Laine 2015*)

The expert interviews were made with known experts, partners and device suppliers. The interviews were very informative especially in the beginning of the study. They advised in setting the baseline for the study by introducing the known abilities of the technologies. They were also very helpful when finding answers to questions rising from articles, seminars and fairs. Expert interviews always provided some tacit knowledge, too. (*Leino, Katajisto and Laine 2015*)

Knowledge dissemination

Finding the most appropriate methods for knowledge dissemination is one of the key elements of developing the technology knowledge transfer model. In the beginning of the research the most potential knowledge dissemination methods were listed as:

- written reports
- workshops
- webinars

- knowledge transfer meetings
- expert reports
- technology demonstrations
- figures and videos
- expert floors
- case descriptions
- events in the enterprises
- technology application pilots

The various knowledge search actions indicated that there are plenty of written material that should be available for the enterprise representatives just in case they need to have a closer study of the case. For this purpose, a knowledge sharing platform was created in the virtual learning environment of the university. On the platform the participants can familiarise themselves also with materials and subjects that they did not name as their primary knowledge needs. (*Leino, Katajisto and Laine 2015*)

Technology demonstrations were distinctly found to be the most interesting and useful knowledge dissemination method. The development of illustrative new technology demonstrations was started during the development of the innovation targeted participatory research process model and it was further developed during the second phase of this whole process. Different kinds of demonstrations were generated mainly for the universities' laboratories. These demonstrations usually presented the general functionalities of various new technologies. They illustrated the basic features of the technologies but also pointed out the requirements and the potentiality of them. Often in the end of the case execution some specific demonstrations were built up based on the needs of the enterprises. These special demonstrations were used to show how the technology could be applied to solve certain specific problems. The demonstrations acted as the attractions of seminars and workshops but they were also examined more closely in the dyadic enterprise meetings. This kind of demonstrations concretise the potentiality of the technologies but they also highlight the challenges of using the technology as well as exclude the unsuitable solutions. (*Leino, Katajisto and Laine 2015*; *Laine, Leino and Pulkkinen 2015*)

The expert reports in this research mean the analyses of the new, discovered technology knowledge written by the knowledge searching experts. The reports describe the knowledge search results usually from a specific need's viewpoint. The reports were found to be useful particularly in the enterprise-specific cases where the expert could offer tangible knowledge for the specific needs of the enterprise. These reports have been used as guidance in decision making of investments and development projects. (*Leino, Katajisto and Laine 2015*; *Laine, Leino and Pulkkinen 2015*)

The technology transfer seminars and workshops are often organized around certain technologies. In these seminars and workshops there is usually one top-ranked expert and always the experts of the universities and device suppliers, presenting different kinds of technologies, applications and demonstrations. This study indicates that it is very important that the presenters speak the first language of the attendees. The top-ranked experts and device supplier representatives should be chosen, according to knowledge needs, to speak about their own special fields while the university experts represent the wider results of the knowledge search. The discussions in the seminars and workshops are a good way to identify the needs for more detailed knowledge. In order to ensure the deeper absorption of knowledge the participants also get written material concerning the subjects of the presentations to which they can refer later on. Again this research showed that one of the most demanding challenges of organising this kind of seminars and workshops is to tempt a reasonable crowd of participants to travel to the event. If the distance from the workplace to the seminar location is significant, say over an hour one way, it will probably take the entire workday and is surely too time-consuming for an SME participant. It is important to convince these participants of the benefits of their participation and then to make sure they really exist. According to the feedback collected in the seminars and workshops, it was especially the presented application examples and demonstrations were found to be impressive and convinced the participants. (*Leino, Katajisto and Laine 2015*; *Laine, Leino and Pulkkinen 2015*)

5.3.5 Innovation oriented model for technology transfer

The second phase of developing the technology knowledge transfer model suitable especially for the universities of applied sciences was carried out with two other UASs and 16 SMEs. In this phase 25 cases altogether were executed in order to find new knowledge and specific answers to the needs of the SMEs. Based on the cross sectional study of all the case studies and best practices identified during the case executions, ‘The innovation oriented model for technology knowledge transfer in HEI-SME collaboration’ was created (FIGURE 16). The actions of technology knowledge transfer proceed vertically according to FIGURE 16. Along with the main phases, there is one grace note in the figure. It illustrates the phase where demonstrations and public workshops help other enterprises recognise the technology needs which they did not identify earlier in the process. These new recognised needs can open novel technology transfer processes.

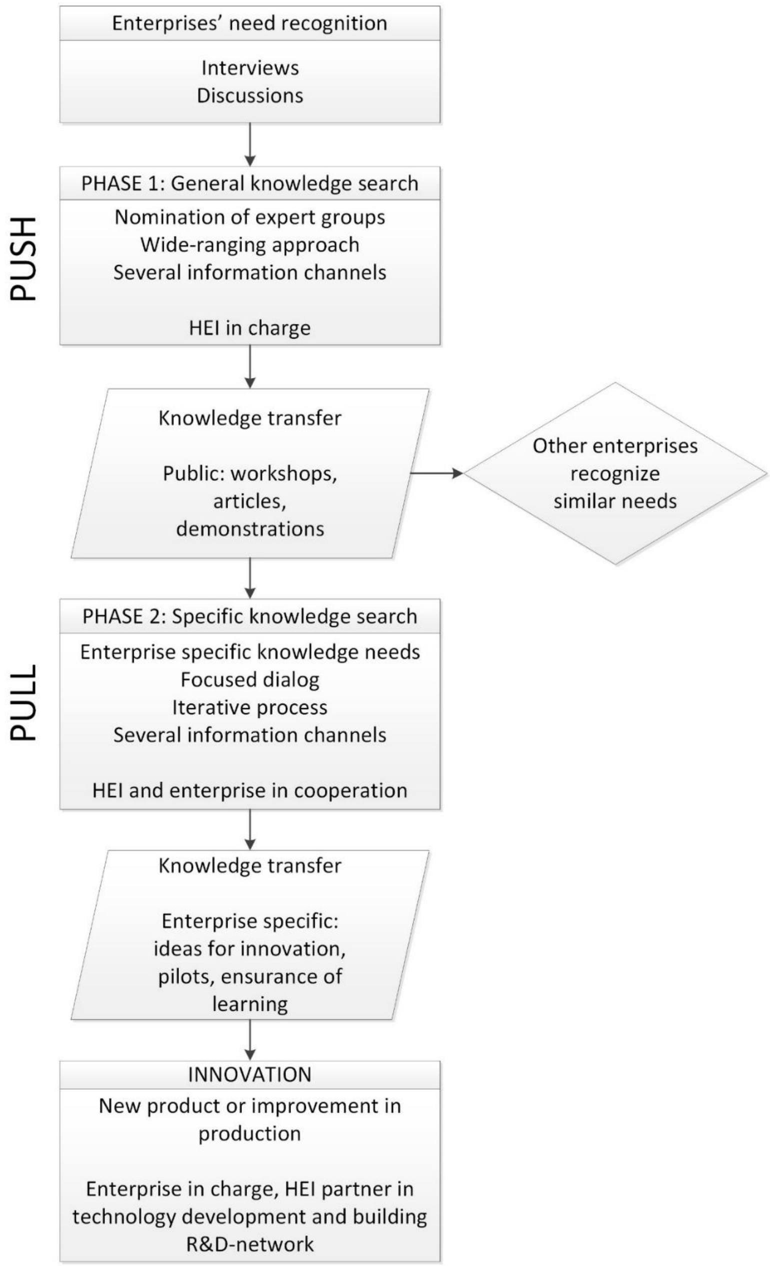

FIGURE 16 Innovation oriented model for technology knowledge transfer in HEI-SME collaboration (*Leino, Katajisto and Laine 2015*)

This research indicates that in HEI-SME collaboration one of the success factors is the university's understanding of the SMEs' business environment from the SMEs' perspective. SMEs:

- have limited resources for development → usually no own R&D -department – often not even one person concentrating mainly on R&D
- already know a potential end customer in the beginning of the development work
- largely rely on device vendors as problem solvers
- yet have situations where they try to expand their knowledge and recognise that external support is needed in order to acquire the necessary knowledge and knowhow

In technology development, HEI is an independent source of information and knowledge. Thus HEI-SME collaboration is usually based on the HEI expertise and independency and SME needs. (*Leino, Katajisto and Laine 2015*)

Innovation oriented technology knowledge transfer begins with enterprise need recognition (FIGURE 16). The SME usually has a vision about the knowledge need. With the discussions and interviews the HEI experts try to identify the real need between all the problems and questions. This step of recognising the relevant problem and actual knowledge need is essential so that the HEI can nominate the right experts for the knowledge search. In collaborative projects the experts can come from different HEIs. The need recognition should concentrate on the relevant needs but also on the future business potential. Based on the need recognition the project plan is formulated and the cooperation agreement is written with the enterprise. At this phase it is essential to have the appropriate expertise and decision making ability from both sides (HEI and SME) at the discussion table. This kind of collaboration should always aim at more continuous partnerships rather than one-time projects, because often new knowledge needs with deeper meaning are recognised through knowledge dissemination and through closer collaboration. (*Leino, Katajisto and Laine 2015*)

On a general level of the knowledge search it would be effective if the HEIs made strategic choices concerning the technology knowledge areas. In some areas the HEI strategically decides to produce new knowledge and novel information by itself and on some areas it just actively monitors new knowledge produced by other HEIs and RDI organisations. The strength of the HEIs is that they usually have multidisciplinary cooperation between different fields. This helps in innovation oriented technology transfer processes, because new technological innovations created in SMEs often use technologies that have been applied in some other field of industry or in bigger companies. In particular, the SMEs, with limited resources and the pressure to succeed in each technology transfer project, prefer the already tried and tested technologies by applying or downscaling them in their product or production innovations. A new technology in an SME does not necessarily mean a radically new technology but e.g. a new kind of application. For this it is essential that the HEI experts have skills to acquire the necessary knowledge from different sources and to refine it in order to fulfil the knowledge needs of the SME. (*Leino, Katajisto and Laine 2015*)

The general knowledge search actions (Phase 1 in FIGURE 16) of innovation oriented technology transfer are defined as PUSH type actions, because the HEI experts have the responsibility of choosing the suitable knowledge channels in order to meet the wide-ranging targets of the case. HEI also takes care of agreeing on the technology transfer practices, including who keeps in touch, with which intensity and how everything should be reported. The HEI pushes the wide-ranging knowledge found in different sources to the SME with a specific need but also simultaneously to other enterprises. In FIGURE 16 the decision symbol (parallelogram on the right) represents the general level knowledge that is shared with other enterprises, who have not even expressed the need of that knowledge. However, the new knowledge may generate new ideas and new knowledge of development possibilities, which then lead to new development decisions. In phase 2 (FIGURE 16) of knowledge search the actions are of a PULL type, because the search is more detailed and focused on the specific needs of the enterprises. The enterprises are pulling the answers out of the HEI so in this phase the dissemination is carried out in a specifically connected way with the detailed questions and needs of the enterprise. (*Leino, Katajisto and Laine 2015*)

The expectations of the enterprises, the success of the previous experiences, the absorptive capacity of the enterprises and the disseminative capacity of the HEI define the knowledge dissemination practices used in each case. The UASs have the advantage of having experts with educational skills and experience of several dissemination methods. However, it is important to ask the enterprises which dissemination methods would help them to utilise the knowledge effectively. Lack of implementation can ruin the entire final result. (*Leino, Katajisto and Laine 2015*)

HEIs usually have their focus areas of research in which they can produce deeper knowledge. In addition to these research areas there are plenty of fields in which they can execute productive applied research for the needs of industry. The ability to apply technology to the needs of the enterprise will determine the outcome. The technology knowledge transfer process is complex, iterative, multi-directional and depends heavily on the existing knowledge, beliefs and experiences of both sides. The results should be primarily measured from the enterprise’s perspective. (*Leino, Katajisto and Laine 2015*)

In the technology knowledge transfer the time horizon of the projects differs from the immediate launch of a new product to years of decisive strategic knowledge construction. The crucial factor in a technology knowledge transfer process is the enterprise’s ability to effectively benefit the new technologies. It is concurrently a question about the enterprise’s absorptive capacity and the HEI’s disseminative capacity. However, the SME's commitment and participation are the key elements to a successful outcome. The HEI is highly responsible for using suitable dissemination methods and channels to ensure that the enterprise understands the results and will be able to exploit the new knowledge. The adoption and usage of new knowledge will remain as the responsibility of the enterprise. When the enterprise has decided to acquire knowledge from outside, it is likely that its staff do not have corresponding knowledge with the HEI’s experts. Therefore, the direct communication between HEI experts and SME representatives has an essential role in the successful knowledge transfer process. Only rarely a mere written report is enough, even though that is also important. (*Leino, Katajisto and Laine 2015*)

5.4 Evaluation of the technology knowledge transfer model

This thesis concentrates on the development of the HEI-SME collaboration driven technology knowledge transfer so that each actor could benefit from the process as straightforwardly as possible. The traditional linear technology transfer models will be replaced with new, non-linear and more HEI-specific models of technology transfer. In this chapter the developing process has been described. The process has had two main phases, which have been completed with several additional steps and research on partnerships and engineering educators' professional development.

The first phase focused on the initial technology knowledge transfer process model. Based on the initial model the targeted open innovation participatory research process was modelled in order to answer the need of refining new knowledge and creating new innovations. The two models of the first phase are different and aimed at different situations, but they do overlap. The focused technology transfer process often creates new seeds or starts for the targeted open innovation participatory research process. The second phase was based on the tests and pilots of the first phase and aimed at the development of the technology transfer and at the combination of knowledge transfer and innovation. As a result of a wider and multidimensional development process the innovation oriented technology knowledge transfer model was created and piloted.

Through the entire thesis, the base for successful technology transfer and open innovation has been in recognising the technology knowledge needs of the enterprises, finding the correct and relevant competences of the HEI personnel and bringing these together in order to find new knowledge and create new innovations. The development has required multiple phases and several testing and piloting steps, which have given essential information on best practices as well as on parts that still need enhancing.

In the first phase of the technology transfer development, the emphasis was on creating the structures and steps, like recognising the enterprises' needs, partnering between HEIs and SMEs as well as effective knowledge search. The partner enterprises have an important role in technology transfer between HEIs and SMEs. In targeted open innovation, a trust based and committed participation as well as an adequate knowledge climate are essential. When enterprises have fully adopted the participatory process model including their responsibilities, the cases have been successful.

When the accumulation and building of knowledge is performed in collaboration between a university and enterprises, active individuals, like students, researchers, educators and enterprise personnel, have a crucial role. In technology transfer the tacit knowledge of the actors is combined with explicit knowledge found in external sources. Particularly the enterprises' tacit knowledge is combined with explicit research knowledge in order to solve the recognised challenges. Therefore, a continuous dialogue between the actors is essential. This research has clearly agreed with Chesbrough's (2003) proposition that external R&D can create significant value but internal R&D is needed to claim a portion of that value. It has also been very meaningful for the model creation, that already in the beginning of the modelling the evaluation step was built as a part of the knowledge transfer process based on design science research method. Evaluation of different cases has given important information which has been used on the later development steps. (*Laine, Leino and Pulkkinen 2015*)

The initial technology knowledge transfer gave the enterprises some clearly valuable information, but it was challenging to make the process model understandable and visible in order to give all the actors possibilities to exploit this information in their work. The knowledge is only truly meaningful when it can be exploited somehow. For this reason, the innovation targeted participatory research process was created. It uses both tacit and explicit knowledge of actors in innovation. It requires trust, but in trustful collaboration the innovation network seemed to develop and the members started to create new practices together. The processes have helped the partners to solve several problems, create new products and services and to make investment decisions based on knowledge. (*Laine, Leino and Pulkkinen 2015*)

Then in the second phase of the technology transfer development the wider perspective enabled the further development of the model. In this phase the main target was to combine the knowledge transfer with the innovation creation. The steps of the model were enhanced in order to focus the technology knowledge transfer on the creation of new innovations. Therefore, the most developed part of the model was knowledge dissemination. Due to earlier experiences the absorptive capacity of the enterprises and the disseminative capacity of the HEI experts were taken into closer consideration. It was proven to be a very appropriate path.

Demonstrating and piloting were found to be the essential dissemination methods in the technology knowledge transfer process. Demonstrating and piloting follow the steps of a design science research method. The needs of the enterprises guide the engineers and researchers in implementing different kinds of demonstrations and pilots. The implementation process gives the creative humans possibilities to design new innovative demonstrations and pilot applications to make the advantages of a certain technology as apparent as possible. Demonstrations proved to be excellent in illustrating the basic features, requirements and potentiality of certain technologies, but also in highlighting the challenges of using the technology and excluding unsuitable solutions. The pilot applications, on the other hand, have proven to give first-hand information and prove the potentiality or unsuitability of the technology in real environment. The pilot applications are often conducted on the basis of demonstrations and first phase knowledge search. The subjects for the pilots arise from the SMEs' needs and they are implemented with the university's equipment as test applications. The demonstrations and pilots have been very positively commented on by the SME partners but also by other visitors and students stopping by at the laboratories. Furthermore, the design science research was found to be a very effective paradigm for defining and structuring both the technology knowledge transfer process and cases in technology transfer. (*Leino and Laine 2016*; *Leino, Katajisto and Laine 2015*)

The entire process of technology knowledge transfer modelling in this thesis led into the innovation-oriented model for technology knowledge transfer in the HEI-SME collaboration. By evaluating this model, it can be seen as a new approach for the need and dialogue based technology knowledge transfer. The actions of the model are focused especially on knowledge increase and innovations in small and medium sized enterprises. The model is non-linear, emphasises the meaning of need recognition and consists of many iterative cycles. The technology knowledge transfer, implemented according to this model, is not just about searching and disseminating knowledge passively but above all, it combines existing knowledge with new searched knowledge, demonstrating the possibilities of the technologies based on searched and interpreted technology knowledge and piloting the technologies in real cases of the enterprises, as well as transferring the knowledge interactively and iteratively in order to find answers and new innovations. This model deepens the collaboration between the HEIs and the SMEs while the model actions proceed, and it increases the responsibility of the enterprises as well as supports the push to pull transformation of the technology knowledge transfer. This new model especially pays attention to the absorptive capacity of the enterprises by demonstrating and piloting the technologies based on the enterprises' needs, and by transferring the technologically interpreted and analysed knowledge by the experts with dissemination skills. (*Leino, Katajisto and Laine 2015*; *Leino, Katajisto and Laine 2016*)

One evaluation result is also the observation that the design science research method as well as the theories of absorptive and disseminative capacities substantially impacted the research work. First they affected the case selection and design work and then the modelling. The strength of the entire two-phase modelling work was in the adequate amount of carefully evaluated real life cases. According to Hevner et al. (2004) the impact of each new design and the entire model was defined by analysing the usefulness, quality and/or the effectiveness of each result. Choosing the appropriate techniques for designing and methods for testing and evaluating the results was crucial, as noticed by Hevner and Chatterjee (2010). The cross sectional study based first on 10 case studies and then in the second phase on 25 case studies was used to develop the technology transfer model especially suitable for SMEs and UASs. A total of 35 case studies was a sufficient amount for making generalisations on the model. In practise the model combines the generalisations of the best practices identified during the development process. (*Leino, Katajisto and Laine 2015*)

As an additional evaluation perspective, one part of the evaluation was made according to the five attributes of widely adopted innovations (Rogers 1995). A widely adopted innovation:

- adds value for the user of the innovation
- is compatible with the values and needs of the user
- is simple to understand
- can be tested without total commitment to it
- results of using the innovation are visible for the user and observers

When comparing the results of developing the innovation oriented model for technology knowledge transfer in HEI-SME collaboration to the attributes introduced by Rogers, the following observations were made (*Leino, Katajisto and Laine 2015*):

- The model adds value for the involved SMEs, accumulates their knowledge base and increases their absorption capacity.
- The knowledge transfer gives the enterprises wider and supplier-independent information of the potential technologies to reach their innovation targets.
- The SMEs can find new knowledge even out of their scope due to the non-linearity as well as the base of interactions and new combinations of knowledge.
- New networks will add value also in the future.
- It is not only what has been created so far, but also building potential and capacity for the future.
- Compatibility with values is not as clear, despite that solving SMEs problems and aiming at new innovations is a very attractive way to tempt SMEs to participate in the process.
- The process may look complex and the subjects can be very complex, but the process is simple with two cycles and continuous interaction.
- HEIs handle a big part of the complexity.
- The level of the SMEs' commitment has to increase during the process.
- The testability is based on the discussions in the beginning of the process and on the two cycles and if the SME is not willing to continue at some point of the process, it can withdraw from it.
- The visibility of the results is apparent for the SME when it uses the knowledge in a new product, service or process development.
- Results are visible for larger audience via publications, seminars, etc. and also when new products or services are released. Process innovations are seldom published.

As a conclusion of this evaluation, this research states that the created technology transfer model has similar properties as the typical properties of diffused innovations listed by Rogers. Furthermore, the SME representatives have given positive feedback on technology transfer. New methods are constantly tested and evaluated. (*Leino, Katajisto and Laine 2015*)

6 The role of research work in engineering educators' professional development

This research studies the modes and impacts of the technology research in collaboration between HEIs and SMEs. The previous chapters described the actions of HEIs in the field of technology research. Engineering educators work as engineering experts or researchers on each action step and the increase of their knowledge and practical knowhow should not be underestimated. This chapter describes how the technology research work encourages the engineering educators to study new technologies and technological innovations as well as to find functional solutions to real development challenges of industry, and how it especially increases the motivation of the educator to integrate new knowledge as part of the engineering students' education.

Engineering education aims at producing future engineers. Graduating engineers should have all the technical knowledge and skills combined with the right attitude and social awareness. They should be able to create new, more complex and naturally sustainable technological innovation. The future working life also prefers them to act like entrepreneurs. Engineering education should now be seen from a totally different angle and for that, engineering educators must also have a completely new touch. This thesis does not provide absolute statements for what are considered the best engineering education methods. It concentrates on one working method that contributes to the quality of the engineering educators' professional development. (Crawley et al. 2007)

One important factor in targeting more competent graduating engineers is the engineering educators' professional development. If we want the new engineers to answer the challenges of the future, also the engineering educators' knowledge and skills must be developed. The development of engineering education often concentrates on the teaching methods and learning studies or on hiring professionals from industry. The approach of this doctoral research is based on several case studies in which engineering educators worked as engineering researchers and in addition to the research results they also developed their practical professional skills. An engineering researcher in this thesis is defined as a researcher who works on practical engineering research cases. From the perspective of engineering educators' professional development, the engineering educators, like teachers, lecturers and professors, work as these engineering researchers in research cases. (*Leino 2017*)

One goal of this research is to find the best practises for an educator-researcher combination and to identify the advantages and challenges of it. At the same time the possibilities of utilising the new technology knowledge in engineering education as fluently and effectively as possible was studied. The results of this research indicate that the participation in applied technology research may increase the engineering educators' knowledge and practical know-how significantly. All the engineering educators who were working as engineering researchers in the research cases noticed the research work as one of the best ways of developing their professional knowledge and skills. Their experiences emphasised the real industrial environments and the tangible needs of the enterprises as well as the will to see and show to others how new technologies work. The applied technology research was seen as an effective way of lifelong learning. (*Leino 2017*)

In addition to knowledge increase the educators saw that they can benefit from the technology knowledge transfer in many ways. They discovered that the research based and enterprise-targeted written materials as well as different kind of demonstrations and pilot applications can be used when teaching the future engineers. All the effort put to the research case can also be utilised in education. This research shows that while technology research based on engineering educators working as engineering researchers is an effective way of answering the enterprises' knowledge needs, it simultaneously improves both engineering educators' practical professionalism and the results of engineering education. This mode for engineering educators' professional development can also be used as a planning tool for the higher education management. (*Leino 2017*)

When an engineering educator has a chance to concentrate on a specific technology research, he/she is able to significantly develop a high level of professional knowledge and practical knowhow. Combined with personal motivation this is a significant advantage in research work and in education but it may also lead to professional publishing, like a scientific article or a textbook. This chapter introduces the best practises for an educator-researcher combination, the advantages and challenges of it and also the modes of benefitting from these practices in professional publishing.

6.1 Engineering Educators as Engineering Researchers

In this thesis the research of engineering educators' professional development is based on a slightly wider group of case studies that the rest of the thesis. This research is based on five different technology research projects implemented in 2008-2016. The following table (TABLE 1) compiles the basic information of these five projects. The number of educators, on the last column, refers to the number of educators working as engineering researchers in the applied technology research, development and innovation cases of these projects. The cases with technology challenges of enterprises were generally described in the previous chapters. This chapter describes the studies of the educators' professional development in these cases. (*Leino 2017*)

TABLE 2 Engineering educators working as engineering researchers in the project cases (*Leino 2017*)

Project summary	**Number of cases**	**Number of educators**
International Technology Transfer pilot project (KVT-SAMK) - searched the latest information on technology from international sources for the use of the involved enterprises	3	5
Applied machine vision research for the needs recognised in the local manufacturing enterprises (Pro Machine Vision) - e.g. demonstrations, pilot applications and educational material	11	4
Universities of Applied Sciences as interpreters of international technology knowledge transfer for SME's (AMK KVTechTrans) - piloting and refining the technology knowledge transfer model with two other UASs and new automation and energy combined knowledge needs - case studies based on need recognition	25	12
Building up an innovation network on Welfare Technology (Common Weal) - Well-being enhancement by personalised and service designed client technology, cases of searching technology or service design solutions to real life client situations or searching new, yet untapped possibilities and technology solutions	3	3
Simulation environment - New extensions to the automation of production, factory simulation cases based on the enterprise needs to build up an environment for increasing simulation possibilities and needs	3	6

All five research projects (TABLE 2) aimed at solving technology problems, challenges or knowledge needs of the enterprises. The engineering educators were closely connected to the cases already in the beginning of the projects, because they were mainly responsible for the need recognition. The general phases and steps of the projects were described in the previous chapters of technology knowledge transfer modelling. The technology knowledge transfer model relies highly on the engineering educators' expertise of specific technologies, local enterprises and knowledge dissemination. This chapter concentrates on the careful evaluation of the educators' work as engineering researchers in these projects. (*Laine, Leino and Pulkkinen 2015*; *Leino, Katajisto and Laine 2015*)

Each RDI case was put into practise in teams consisting of engineering researchers and project engineers. The team took care of both the technology knowledge search and the practical RDI actions. The engineering researchers also analysed the cases and identified the best practises. The engineering researchers evaluated the results of each case and project and created as well as refined the model for technology knowledge transfer in the project context. They were also mainly responsible for the knowledge dissemination. (*Leino 2017*)

Engineering educators working as engineering researchers have the significant advantage of having the competence to transfer the new knowledge to the enterprises as distinctly and understandably as possible. Experienced professional educators know how to pay attention to the absorptive capacity of the enterprises. And as a counterpart of absorptive capacity, the disseminative capacity can be seen as one of the core competences of the engineering educators in technology knowledge transfer. Consequently, when the engineering educators worked as engineering researchers the absorptive capacity of the enterprises and the disseminative capacity of the higher education institutes met in a productive way. The following subchapters emphasise the multifaceted value of knowledge transfer made by the engineering educators who worked as engineering researchers in these cases. (*Leino 2017*)

6.1.1 Research work boosting the teaching material

In technology knowledge transfer the first steps of the knowledge search aim at producing a technology specific overview of the general development in that field. These summaries are often introduced as online material like written reports, figures and videos. For example, the web site of machine vision basics was generated for enterprises who were interested in the possibilities of machine vision in manufacturing. The web site explained the basic features of machine vision and introduced the possibilities of exploiting it, but also answered to the specific knowledge needs and listed application examples. (*Leino 2017*)

The engineering educators are used to create descriptive technology material. Although the web site and the material were targeted for the enterprise representatives, without any extra effort the educators could also use them as teaching material on their courses for the engineering students. Thus, while the enterprises received the information that they could use when planning the manufacturing, the educators increased and deepened their knowledge and the students got the newest facts on the field of machine vision. Moreover, in every step of the knowledge transfer the educators can benefit the RDI work as examples introduced on their lectures. (*Leino 2017*)

6.1.2 Illustrative technology demonstrations

The previous chapters indicated that the practical technology demonstrations are found to be a popular method of knowledge dissemination. Since the demonstrations base on the recognised needs of the enterprises, they illustrate the usability of the technology but also present the basic features of it. Although the demonstrations are usually made for certain purposes of the enterprises and the knowledge dissemination, they can be used without any extra effort in the engineering education too. The practical demonstrations give the students possibilities to concretely go further in exploring the new technologies. The demonstrations have been made according to the deep evaluation of different technologies and different ways of using certain technology, so they offer deeper information than just texts and figures on a book. During the development of the technology knowledge transfer model more than 30 different demonstrations have been built for the use of technology dissemination and engineering education. (*Leino, Katajisto and Laine 2015*; Leino and Rantapuska 2012; Leino et al. 2014)

This research indicates that designing and implementing the demonstrations increases the knowledge and practical skills of an engineering educator, but also gives tools for the illustrative education of engineering students. Parts of the demonstrations are also filmed as educational videos, which can be more easily presented outside of the laboratory. The demonstrations have received good feedback from both the enterprise representatives and the students. They have appreciated both the general level demos and specific, case-combined demos. The engineering educators have underlined the demonstrations in illustrating the basic features, requirements and potentiality of the technologies, but also in highlighting the challenges of using the technology as well as in excluding unsuitable solutions. (*Leino, Katajisto and Laine 2015*; Leino and Laine 2016; *Leino 2017*)

6.1.3 Real industrial technology pilots

The knowledge search and demonstrations have generated needs for more specific, enterprise-combined technology pilots. The pilot applications were again designed and implemented by the engineering educators who were working as engineering researchers in the technology knowledge transfer projects. In most of the cases the pilot applications were implemented as parts of the enterprises' manufacturing lines. This way the enterprises had chances to test them for weeks or a couple of months and they received first-hand information of the pilots and the applications prove the potentiality or unsuitability of the technology in real industrial environment. During the development of the technology knowledge transfer model more than ten different pilot applications have been designed and implemented. (*Leino 2017*)

Again, the pilots, implemented by the engineering researchers, gave real industrial experiences with new knowledge of technologies. The educators learned the new practices, little details and possible difficulties of using the technology. At the same time the students had the chance to work together with the research team in real industrial cases, experiencing applied research activities during their studies. When the educators have personal experiences of implementing the pilot applications they can use these cases as illustrative case examples in their lectures and teaching material. (*Leino 2017*)

6.1.4 Publications

The Finnish Ministry of Education and Culture as the main financier of the Finnish universities of applied sciences obliges the UASs also to publish their research results and professional articles (Universities of Applied Sciences core funding 2015). Applied research, like the different actions made with the enterprises in the technology knowledge transfer, offer plenty of subjects for articles and publications. These publications can be for example general level stories in newspapers or magazines, more professional articles in trade papers or more scientific articles in conferences and journals. During the development of the technology knowledge transfer model more than 70 articles of various kinds have been published in the research projects related to this thesis.

When an engineering educator has possibilities to work as an engineering researcher and participate in real industrial research cases and the personal motivation is on a high level, the educator's expertise can reach such a level that the educator can even write a textbook or a chapter for a textbook for engineering education. Within this doctoral research a chapter on Machine Vision in Smart Health and Social Care was written for a textbook, Introduction to Smart eHealth and eCare Technologies. This chapter introduces the principles of machine vision and describes the possible modes of exploiting machine vision in smart health and social care of the future. (*Leino and Valo 2017*)

6.2 Research work fostering the professional development of engineering educators

As a part of this thesis the experiences of engineering educators working as engineering researchers in 45 different research and development cases were studied. The cases were executed within research projects, which aimed at new technology knowledge and innovations. This part of the doctoral research concentrated on identifying the best practises of engineering educators' professional development in research work. (*Leino 2017*)

The experiences of the educators are based on their interviews and discussions with them after each technology case. The general best practices were identified by analysing the experiences and combining similar comments. The results of this research indicate that applied technology research work may increase the engineering educators' knowledge and practical knowhow significantly. Undoubtedly personal motivation has a significant role in the knowledge increase. Applied research work was disclosed as one of the best ways for professional development by all the interviewed educators. They emphasized the real industrial environments and need based research and development as well as their personal will to see and show to others how new technologies work. However, more than half of the educators mentioned that most of the cases required more work that the initial thought was. On the other hand, they commented that harder work also generated higher learning results. The role of applied technology research was seen as an effective way of lifelong learning in engineering educators' professional development. (*Leino 2017*)

In addition to knowledge increase and new teaching material, demos and pilots were considered very motivational and an important incentive for participation. The educators believed that their new knowledge, new materials and interesting real-life examples will also motivate and inspire the students. In this research the most important factors for the educators in organising research collaboration between higher education and industry were listed to be (*Leino 2017*):

1. Careful need recognition in the enterprises as the basis for educator recruitment
2. Choosing motivated engineering educators with sufficient knowhow on the specific field of technology to work as engineering researchers
3. Building up functional research teams for each case
4. Providing adequate resources for the teams to
    a. combine existing knowledge with new searched knowledge

b. demonstrate the technologies
c. pilot the technologies in real cases of the enterprises
d. disseminate the knowledge interactively and iteratively in order to find answers and new innovations

The meaning of successful technology development and practical solutions may not be over emphasised. They were found to be important in building the self-esteem of the educators and thus motivating them to integrate the new knowledge as part of the engineering education. Educators who worked in more than one of the research projects reported that after every case the integration of the new knowledge to education was more and more fluent. This indicates that in the long run the integration of new knowledge into daily actions of engineering education will be even smoother. (*Leino 2017*)

The technology knowledge transfer model developed in this thesis consists of need recognition, technology search, knowledge reinforcement and a wide range of knowledge dissemination. Many of these procedures require deep technology knowledge but also high disseminative capacity. Engineering educators often have both of these requirements, so they are good candidates for working as engineering researchers in the technology knowledge transfer targeted research projects (*Leino 2017*). One of the engineering educators summarised the importance of the research work like this:

> "While we carry out research, development and innovation work with the enterprises, our knowledge increases all the time and that new knowledge we can share to our students!"

7 Modelling of collaborative technology research activities between higher education institutions and industry

This research is essentially a discourse of interactions between HEIs and enterprises, especially small and medium sized enterprises (SMEs). The modelling of the actions and procedures have aimed at interaction that can add value for both sides. In Finland, SMESs employ 64% of working people and they consist 60% of value added in non-financial sectors (EU 2015). These percentages vary across Europe but the general fact is that SMEs have a significant role in employment and value creation. In addition to this, SMEs do not often have adequate resources for technology knowledge acquisition. These two observations set the SMEs up as the primary target group of this research.

In order to succeed in networked collaboration, all the participants should perceive the benefits of the cooperation. Consequently, the added value of the university-industry cooperation should be seen from the different perspectives of the participants. In addition to the SMEs also the universities together with their experts, the students and the surrounding society can benefit from the well organised HEI-SME collaboration. Therefore, all these winners of the collaboration are named as the target groups of this research.

The technology knowledge transfer process, modelled in this research, aims at innovations. This means that the goal of the work is not "just" to search and find technology knowledge and transfer it to the enterprises as interpreted and enriched knowledge but to achieve a higher level of technology knowledge transfer in order to create targeted open innovations according to the new technology knowledge. This doctoral thesis indicates that it requires closer collaboration, mutual trust and shared research interests between SMEs and HEIs. Closer collaboration makes it possible to create the shared knowledge climate and in that way to achieve the shared innovation flow. The universities are in charge of channelling the partners to this flow. The methods, like workshops, demonstrations and pilots, for the channelling have been introduced earlier in this thesis. (*Leino, Katajisto and Laine 2015*; *Laine, Leino and Lähdeniemi 2016*)

7.1 Fostering promoted value

One goal of this research was to recognise and identify the promoted mutual values that could be achieved in RDI collaboration between HEIs and SMEs. The promoted values were identified based on their abilities to foster shared innovation. At this point of the research the view angle was wider as the advantages of the collaborative research were identified from the different perspectives of SMEs, universities and their experts, students and the whole surrounding society. With the identified and listed promoted mutual values the wider significance of the collaboration can be expressed more visibly. The following table (TABLE 3) describes the promoted values identified in the analysis of the technology research cases. The values are tabulated by the steps of the interaction process and by the beneficiaries. (*Laine, Leino and Lähdeniemi 2016*)

TABLE 3 Promoted values for the participants in different phases of the collaborative research process (An advanced modification from *Laine, Leino and Lähdeniemi 2016*)

PROMOTED VALUE	**For Enterprises**	**For University / Researchers**	**For Educators / Students**
Partnership	Systematic, privileged problem solving based on their own process data, need-based competence development of personnel, documented results	Understanding of local knowledge needs, new research-based knowledge, specialist lecturers, work placements for the personnel	Subjects for theses and student projects, trainee opportunities, understanding of knowledge needs in the field of studies
Need recognition	Identified and classified needs in a structured and prioritised mode	Knowledge of needs and problems in the industrial SMEs	Knowledge of needs in professional knowhow
Knowledge search	Focused facts and methods	All new knowledge and knowledge sources	Up-to-date expertise and ideas for new education
Demonstrations	New ideas and understanding of new technologies	Knowledge of possibilities and obstacles based on hands-on experience	Prepared demonstrations and learning environments fostering the learning outcome
Pilots	Hands-on experience, recognition of possibilities, challenges and unfit applications	New knowledge and knowledge sources as well as practical RDI skills	Real industrial engineering possibilities and experiences boosting the professional development
Dissemination	Knowledge to support investment and development planning	Dissemination knowledge and new methods	Attraction, motivation and trust to new technologies
Innovation	Practical, supplier-independent solutions	Knowledge of targeted open innovations, practical engineering skills	Examples and experiences, entrepreneurial thinking
Evaluation	Understanding of possibilities and obstacles	Best practices for modelling, understanding of enterprises and needs, publications	Subjects for publications, deeper knowledge which enables supervision of more demanding thesis works

The table of promoted values (TABLE 3) of HEI-SME collaboration confirms that carefully designed and goal-orientedly implemented collaborative research activities bring added value to all of the parties. The partnerships with shared knowledge climate enable systematic need recognition and prioritised problem solving for the partner enterprises. With a HEI who knows the products and production solutions of the enterprise the RDI actions are also followed by well documented results. At the same time the HEI can understand the deeper needs of the local enterprises and increase their research-based knowledge. The HEI can also invite specialist lecturers from the partner enterprise and send lecturers for work placements in the partner enterprises. Close collaboration with partner enterprises offer thesis and student project subjects as well as trainee opportunities for students. While working and learning with the enterprises the students will also accumulate their understanding of knowledge needs in the field of their studies.

The need recognition helps the university to understand the knowledge and development needs of the industry and motivates the educators and students to qualify themselves in certain technologies, but it also helps the enterprises to structure their challenges and prioritise the development needs and future steps. Respectively, the knowledge search brings new knowledge to all the parties but it also opens new networking paths and brings ideas for educational development. For example, a scientific literature review offers wide-ranging new knowledge for the university and researchers, while one significant research paper, found in this process, may be the key finding for the enterprise's specific need. (*Laine, Leino and Lähdeniemi 2016*)

In the HEI-SME collaboration researched and modelled in this thesis, the demonstrations and pilots have a significant role. The success of the dissemination bases highly on them. Concrete demonstrations help the enterprise representatives understand the basics of the technologies and to create new ideas for solving the real world challenges. At the same time, the researchers increase their knowledge based on experienced possibilities and obstacles of applying certain technologies. In addition to knowledge increase, the educators will always have fully prepared illustrative demonstrations and learning environments for educational purposes. (*Laine, Leino and Lähdeniemi 2016*)

The pilot applications go deeper into the need. They require more detailed knowledge and ability to solve real development challenges. The implementation of the pilot applications is based on machines and equipment owned by the university. Therefore, the value for the enterprises comes with the hands-on experience of applying a certain technology to a certain identified problem or development need without major purchases. The pilot applications concretely show the possibilities of utilising the technology, highlight the challenges as well as exclude unfit applications. The value for the researchers as designers of the pilots come up as the new knowledge and knowledge sources for technology research, whereas the students value the possibilities to join in real industrial application development processes during their studies. (*Laine, Leino and Lähdeniemi 2016*)

In the technology transfer process the dissemination is mainly directed for the enterprises. Its value for the enterprises is in significant knowledge that can be used for example in planning of the investments and development projects of the company. The value for the universities and researchers comes up with new dissemination methods and with the knowledge in targeted dissemination methods. At the same time the educators and students can increase their understanding of principles and the possibilities of utilising the technologies. Besides, a devoted educator generates interested and motivated students. (*Laine, Leino and Lähdeniemi 2016*)

This kind of successful technology knowledge transfer will more than likely lead to innovations. A multistage, innovation targeted research process with a responsible university ensures that the enterprises get practical and supplier-independent solutions for their challenges. It also boosts the university researchers' enthusiasm and knowledge of targeted open innovations. And, at the same time, while the students experience innovation processes, their entrepreneurial thinking is developing and spin-offs are more likely to emerge. (*Laine, Leino and Lähdeniemi 2016*)

The final but not in any way less significant phase of the technology knowledge transfer process is the evaluation, which is done by reflecting the beneficiaries. The value of the evaluation is mainly in understanding the values of the entire process. It helps the enterprises to understand the possibilities and obstacles in utilizing new technologies but also the value of HEI-SME collaboration. It clarifies the meaning of the best practice identification in model construction for the university and helps them understand the differences between enterprises and their RDI needs. For the researchers, educators and students the evaluation gives subjects for publications, plenty of topics for thesis works and through the increasing expertise, ability to tutor more and more challenging thesis works. As the number of publications is one of the elements of Universities of Applied Sciences core funding, it is important to have subjects for flowing publications (Universities of Applied Sciences core funding from 2015). (*Laine, Leino and Lähdeniemi 2016*)

7.2 W^4 – a quadruple model for collaborative technology research activities between higher education institutions and industry

This thesis has focused on the development of partnerships and modelling of technology knowledge transfer between higher education institutions and industry as well as on identifying of best practices of RDI-education integration, so that the new technology knowledge can be harnessed as a part of the graduating engineers' competence profile. As a result of this research work the W^4 – a quadruple model for collaborative technology research activities between higher education institutions and industry (FIGURE 17) has been modelled. The W^4 model combines the actions models of partnerships, applied technology research, technology knowledge transfer and engineering educators' professional development, which have been introduced in this thesis. The abbreviation, W^4, illustrates the purpose of the model, as it creates a WIN-WIN-WIN-WIN situation to the innovation environment. When the HEIs and industry work together according to the model, all the participants, enterprises, HEIs, students and the surrounding society, win as collaboration creates several advantages to all of them.

The traditional technology transfer between universities and enterprises has focused mainly on IP rights, patents, licensing and the commercialisation of the research results whereas the modern technology knowledge transfer means much wider actions with different operation channels and mechanisms (Perkmann and Walsh 2007). This research states that especially in HEI-SME collaboration the recognition of the enterprises' needs, the identification of the requisite knowledge and ensuring that these meet in fruitful way, guarantee that the results are useful. The W^4 model compiles all the relevant actions of modern technology transfer based on the enterprises' needs, describes the essential elements of the interaction as well as illustrates the added value for the participants.

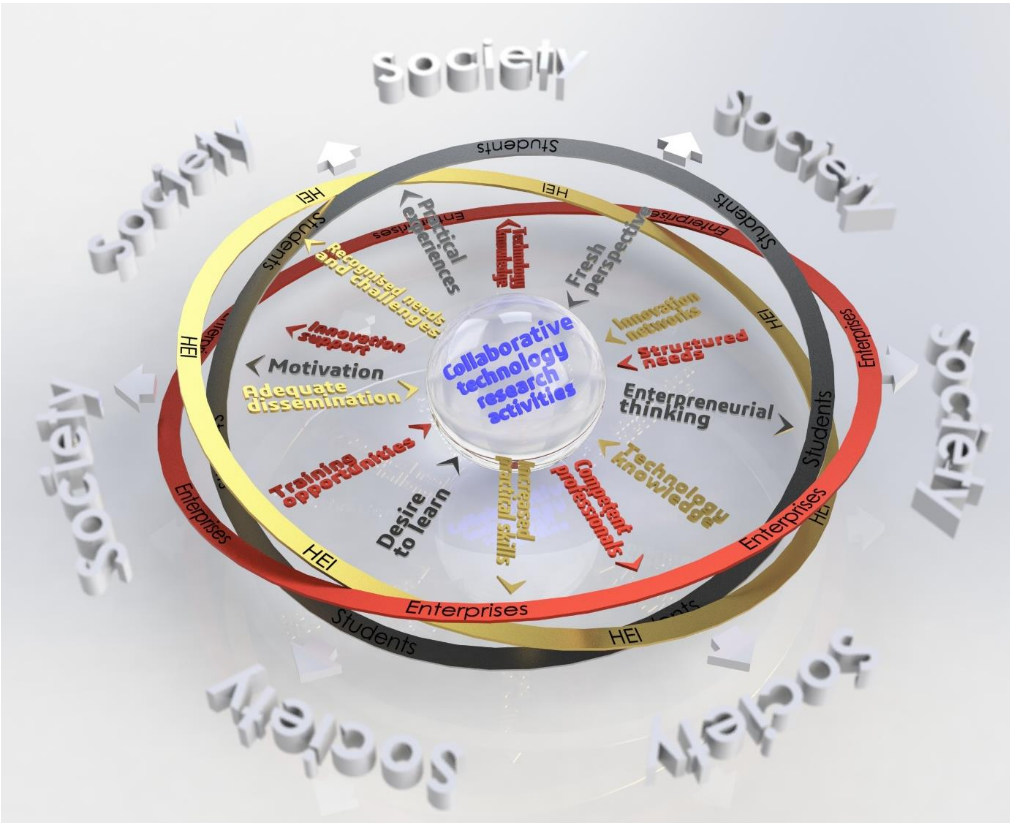

FIGURE 17 W^4 model

In the middle of the W^4 model there is the circle of the collaborative research activities between higher education institutions and industry. The circle illustrates all the actions that are realised in partnerships and in technology knowledge transfer based research described in previous chapters. Around the circle of the activities there are the three rings illustrating the three main dimensions of the collaboration: HEI, enterprises and students. The rings touch each other in many points like these actors touch each other in daily interactions. Between the circle of actions and the rings of actors there are arrows illustrating the added values that the actors bring to the collaboration and get out of it. Around all this is the fourth dimension of the model, the society, enjoying the positive impacts of the collaboration.

In this model the society means all the enterprises, organisations, third parties and individuals who benefit from the W^4 model. By means of the collaboration the society gets developing enterprises and new innovations boosting the economy. The society also gets a functional HEI-SME collaboration, which returns competent new professionals with practical skills and attractive, local HEI with inspiring and motivational education. This can increase the regional attraction and generate higher education based start-ups. As a summary, the W^4 model presents a WIN-WIN-WIN-WIN situation that consists of HEI, enterprises, students and society all pulling together.

7.3 Analysis of the W^4 model

The W^4 - a quadruple model for collaborative technology research activities between higher education institutions and industry – shows how enterprises, HEIs and students bring their needs and knowledge to the shared platform of collaborative technology research activities and as a result of the activities they all gain something, something significant and meaningful. When the enterprises openly bring their technology needs and challenges to the process of collaborative activities, the HEIs can identify and allocate their expertise to these purposes and engage students to work in the processes. Some of the benefits proceed straight to the society and some of them refine in enterprises, HEIs and among students and then move to the advantage of the society.

The analysis of the W^4 model indicates the versatility of the model. In the next figure (FIGURE 18) the main additional values that the enterprises bring to the collaboration and on the other hand the ones that they get out of the collaboration are presented as a separate part of the model.

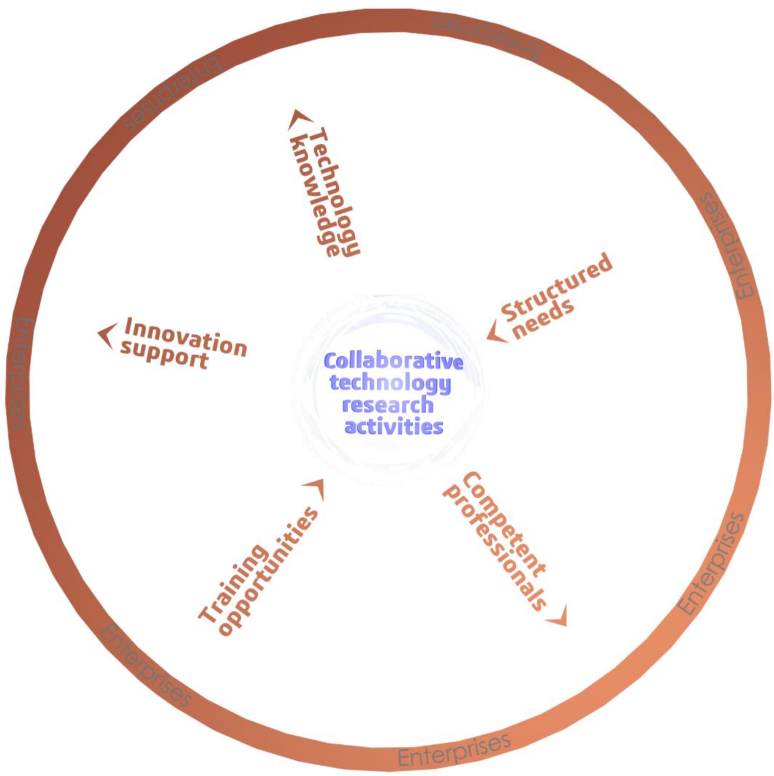

FIGURE 18 Main additional values brought and gained by the enterprises in the W4 model.

The analysis indicates that as a result of the diverse research activities the enterprises can gain a wide set of benefits:

1. The enterprises get their identified needs listed in a structured mode.
2. The enterprises get focused facts and methods of new technologies together with new ideas for the development.
3. The enterprises get practical technology experiences with knowledge of possibilities, challenges and unfit applications.
4. The detailed results give specific knowledge to support investment and development planning of the enterprises.
5. The enterprises get practical, but supplier-independent solutions for their problems, as the HEIs are not selling any equipment or machines.
6. The enterprises get deeper understanding of possibilities and obstacles of benefitting certain technologies.

7. The interaction and conversations between enterprises, HEI experts and students help the enterprises reflect their ideas in order to foster future collaboration and innovations.

8. In wider partnerships the enterprises can get more systematic help for their problem solving.

9. As a result of the technology transfer and collaborative dialogue the enterprise can also identify the future business potentials.

In the next figure (FIGURE 19) the main additional values that the HEI brings and gains out of the collaboration are presented as a separate part of the W⁴ model.

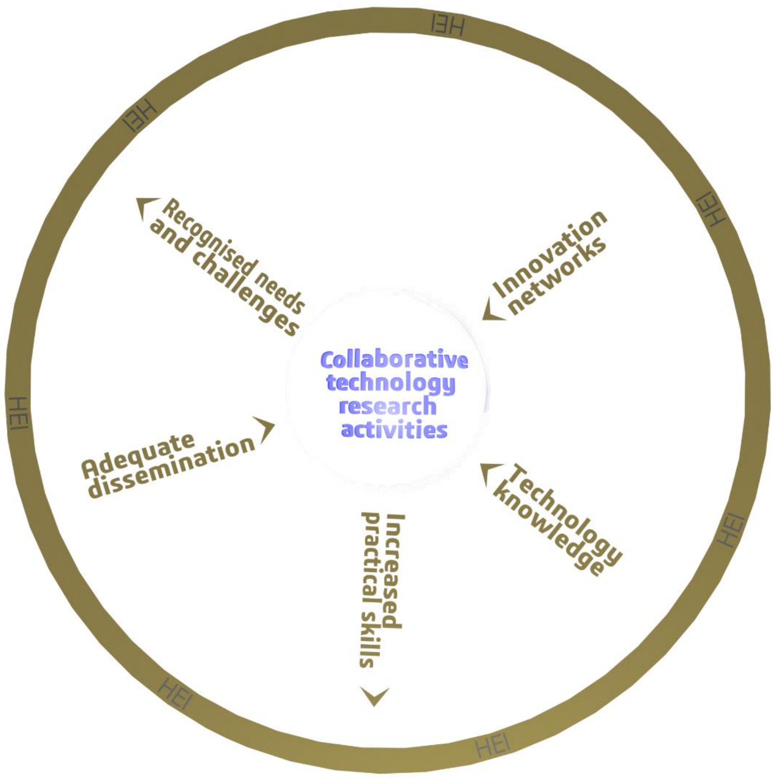

FIGURE 19 Main additional values brought and gained out of the collaboration by the HEI in the W⁴ model.

The analysis indicates that the HEIs act like responsible partners in the processes and ensure that the actions are executed as planned. At the same time:

1. The HEIs can control the actions so that they can also benefit from the collaboration by themselves.

2. The HEIs increase their knowledge and understanding of SMEs' needs and challenges.

3. The HEIs find new knowledge sources and increase their knowledge of new technologies.

4. The HEI experts increase their practical RDI engineering skills but also their knowledge of possibilities and obstacles of using certain technologies.

5. The important work of technology knowledge dissemination generates knowledge of dissemination and new dissemination methods.

6. The innovation targeted research carried out in collaboration between HEIs and industry increases the HEI experts' knowledge of targeted open innovations but also gives possibilities to identify best practices in order to model and develop the processes.

7. From the HEIs perspective these processes are important also because they give many useful subjects for publications, which are one way to increase the funding for the HEI.

8. The better the HEIs know the SMEs and their needs and challenges the better they can answer to the engineering education needs of the future.

9. Comprehensively this kind of collaborative technology research ensures the up-to-date expertise of the HEI experts and gives ideas for new, effective education.

In the following figure (FIGURE 20) the main additional values that students bring and gain out of the collaboration are presented as a separate part of the W^4 model.

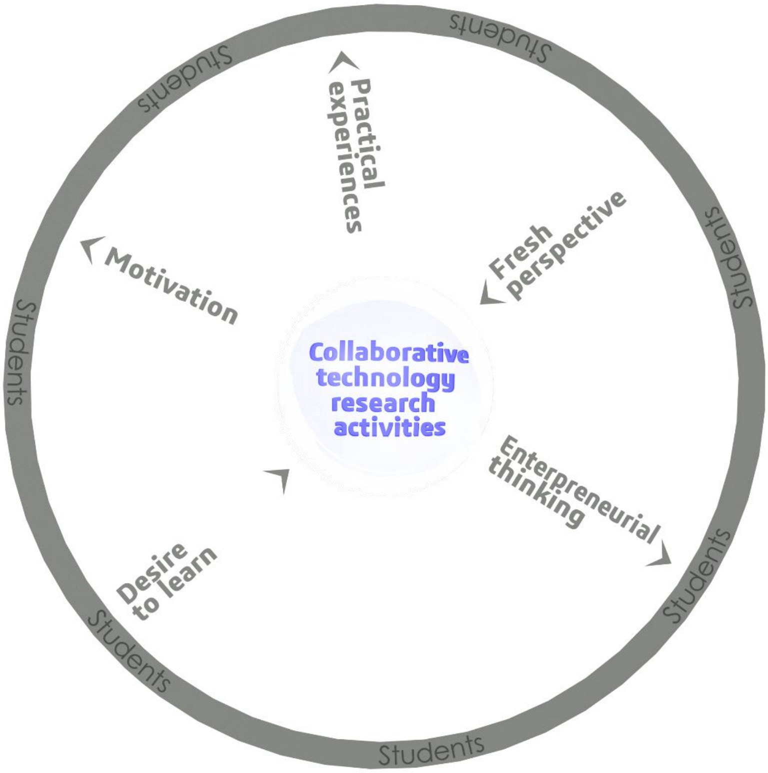

FIGURE 20 Main additional values brought and got out of the collaboration by students in the W^4 model.

The analysis of the model points out that students have a great yet not very visible role in the W^4 model:

1. Students get to know the enterprises and work in research processes.
2. They increase their knowledge of necessary professional knowhow and develop their up-to-date expertise.
3. The new demonstrations created in the processes are always used in engineering education and the demonstrations and research laboratories built up for research purposes are used as learning environments in fostering the learning outcome.
4. The real industrial engineering possibilities and experiences boost the professional development of students.
5. One of the most important element of student experience in collaborative technology research activities is the attitude of the students.
6. By taking part in real industrial RDI projects students foster their attraction, motivation and trust in new technologies.

7. It can also improve their self-knowledge and thus develop their entrepreneurial thinking.

8. As a result of the collaboration the students become competent new professionals with practical skills.

The analysis of the W^4 model confirms that the quadruple model for collaborative technology research activities between higher education institutions and industry is a new approach for the need- and dialogue-based HEI-industry collaboration. It takes all the actors: enterprises, HEIs, students and the society, into account and illustrates their actions in the collaboration. The three dimensionality of the model represents the multidimensionality and versatility of the actions. The model also describes the iterative actions between the different actors and expresses the connections between them.

The analysis shows that the model is clearly non-linear and answers the requests of new, HEI specific and regionally focused models of technology transfer based collaboration. The model discloses both distinct and tacit actions and benefits of the collaboration. It emphasises the fact that all of the actors should benefit from the collaboration in order to create long-term partnerships and achieve significant development. The model also highlights the benefits that the actions executed according to the model generate for the surrounding society.

8 Conclusions

This doctoral thesis has concentrated in an evident need for new, more practical models of collaboration between higher education institutions and industry in European universities. EU, the national governments and especially the national economies demand that there should be more goal-oriented actions for technology transfer and collaboration between HEIs and business so that the research and innovation results can be capitalised faster and more effectively (European Commission 2011; Universities of Applied Sciences core funding 2015). At the same time, there are plenty of different actors in this field of research and innovation as well as in the business sector. The special characteristics of national and regional actors bring another dimension to the development and lead to the need of more individual models.

The European Commission actively works in the field of higher education. The EU objectives of the work are, among other things, to increase the number of higher education graduates, to improve the quality and relevance of teaching and learning as well as particularly strengthen the knowledge transfer based innovation (EU activities in the field of higher education 2017). On the other hand, the European Council requires more actions on the development of partnerships and deeper collaboration between educational institutions and enterprises. The Council also calls for facilitating the opportunities of life-long learning opportunities (European Commission 2011). The requirements of EU and national governments but also the practical experiences have led to the situation where universities across the Europe have considered and developed their collaboration activities with the business sector.

The importance of knowledge and knowledge-based innovation will increase in the future development of products and services. One key factor in the knowledge-based development is the deeper and more powerful collaboration between higher education institutions and industry. The knowledge based collaboration fosters itself because it will most likely create new knowledge. Knowledge creation, knowledge transfer and knowledge exploitation follow each other or even overlap each other.

Several studies have concluded that the traditional technology transfer has come to a turning point and new models are needed. This thesis has tackled this question by approaching the key activities of the HEI-Industry collaboration and deeper finding of the most significant factors affecting the success of the innovations as well as the professional development and knowledge increase of the experts in the research work and in the enterprise collaboration of the higher education institutions.

The Finnish higher education institutions (HEI) have developed methods for their basic and applied research since the Ministry of Education and Culture has obligated them to carry out scientific and applied research as one of their main objectives. This thesis has concentrated on modelling of research, development and innovation actions of HEIs, which aim at quality and practical RDI collaboration with enterprises as well as at close integration between RDI actions and education. The research material consisted of the research projects concerning partnership development actions, technology research, development and innovations as well as technology transfer. The goal was to find connective factors and working methods, which can be utilised and focused on the research, development and innovation work at Finnish HEIs but also be shared with other European HEIs in the future. In addition to all this, the impacts of the RDI work were studied in order to find the most effective factors affecting the integration of RDI and education and the engineering educators' professional development.

8.1 Summary

This research started with the modelling of the partnerships between HEIs and enterprises. According to the research, the partnerships vary a lot, but similar process phases and elements may be found in each of them. By generalisations these phases and elements have been modelled as the best practice model for partnerships. The partnership model emphasises the importance of trust and knowledge climate creation. The research results also indicate that it is essential to create clear goals for the partnership, to agree on operational actions and time scales, and to pursue concrete results with mutual benefits for all of the partners.

The first research question asked, which factors are mostly affecting to the success and impressiveness of HEI-Industry collaboration and its sub questions focused on how the enterprises identify the expertise of HEIs, how the HEIs get familiar with the fields of enterprises and how the trust is achieved. As an answer to the first research question and its sub questions, the partnerships were studied as described in chapter 3. This research confirms that partnerships between HEIs and enterprises generate several benefits, like new learning outcomes and need based competence development of the personnel. At the same time the research states that partnerships require constant development of processes and actions but on the other hand the development of collaborative actions also create trust. In any case, this research indicates that well-functioning partnerships help the enterprises to identify the expertise of HEIs and the HEIs to get familiar with the fields of the enterprises. The partnerships create research based knowledge to support the innovation processes of the industry, foster new innovation creation and recognise new opportunities for future collaboration. The research of partnerships revealed that the HEIs should more vigorously set their own goals already in the beginning of the process. This remark led to the next phase of this research where the technology knowledge transfer was researched, developed and modelled in order to find ways to set mutual goals for the collaboration.

One of the basic ideas of this thesis has been that as technology knowledge creates the base for innovations, for enterprises it is worth to adopt the newest technology knowledge in order to develop and create innovations. This means that there is a growing need for deeper and more productive interactions between higher education based research and industry. In this thesis the applied technology research process and its factors at HEIs have been researched in order to achieve more productive ways for innovation.

The second research question asked, which factors mostly affect the collaborative applied technology research and innovation between HEIs and industry. Its sub questions focused on HEIs' ability to absorb the agile procedures in initiating the new development projects and on the enterprises' absorptive capacity and level of commitment affecting to the development work. In order to find the answers to these questions, the applied technology research cases were executed in collaboration with the enterprises in the fields of automation and well-being enhancing technologies as well as in developing the partnerships and technology knowledge transfer like described in chapters 4 and 5. The actions and procedures performed in these cases have answered to the research question. The answers indicated both the big picture and the little details, which were then used in the modelling of the processes.

This thesis has concentrated on the applied technology research that aims at solving evident, real world challenges. This does not understate the significance of basic research, which has the most remarkable role in new technology innovations. The role of UASs, in this thesis, has been defined as the technology knowledge interpreters between basic research and enterprises, especially SMEs. The technology knowledge transfer modelling has been based on applied research cases, in which the research knowledge and practical skills have been combined in order to answer the needs and challenges of the enterprises. The main goal of the research work has been to apply new technologies to new cases and to create new applications. The factors impacting to the different applied research cases have been identified from the different perspectives of enterprises, HEIs and students. The generalisations of the identified factors have then influenced the modelling.

The partnership modelling and versatile experiences of applied technology research raised the need for a more organised research model in order to make sure that the enterprises can benefit from the research results. And when the literature review proved the presumption whereby the traditional technology transfer had come to a turning point, where the HEIs must create their own technology transfer models to support and boost their research activities, the need for a technology knowledge transfer model suitable especially for the HEIs and for regional development was evident (Perkmann and Walsh 2007; Bradley et al. 2013).

In order to answer to the third research question concerning innovation targeted technology knowledge transfer suitable for both HEIs and industrial SMEs the technology transfer development and modelling has been carried out in two main phases like described in chapter 5. The research generated three different models for technology transfer. Both phases were based on true innovation collaboration and processes between HEIs and industry. As the result of the first phase the initial "process model for international technology transfer" as well as the wider, more open and especially innovation targeted "innovation targeted participatory research process model" were created. In the second phase of the modelling, two other universities of applied sciences participated in the process so that the model could be developed into a more general mode and introduced and shared to other HEIs.

The entire process of technology knowledge transfer modelling generated the "innovation-oriented model for technology knowledge transfer in HEI-SME collaboration". This model is a generalised combination of the first two models. It is a new approach for need and dialogue based technology knowledge transfer. The model focuses on knowledge increase and innovations in SMEs. The model is non-linear, emphasises the meaning of need recognition and consists of many iterative cycles. The technology knowledge transfer of this model is not only about searching and disseminating knowledge passively. Above all, it combines existing knowledge with new searched knowledge. It also demonstrates the possibilities of the technologies based on searched and interpreted technology knowledge and piloting the technologies in real cases the enterprises work on, as well as transferring the knowledge interactively and iteratively in order to find answers and new innovations. This research states that the technology knowledge transfer, implemented according to this model, deepens the collaboration between the HEIs and the SMEs while the model actions proceed. The model also aims at increasing the responsibility of the enterprises and supports push to pull transformation of the technology knowledge transfer. As an answer to the third research question and its sub questions, this new model concentrates on the absorptive capacity of the enterprises by demonstrating and piloting the technologies concretely based on the enterprises' needs, and by transferring the technologically interpreted and analysed knowledge by the experts with dissemination skills.

In order to find answers to the fourth research question concerning the possibilities of modelling the new knowledge of HEI experts that is transferred promptly and fluently to higher education, the experiences of engineering educators working as engineering researchers were studied like described in chapter 6. The aim of this part of the research was to identify the best practises of engineering educators' professional development in the research work (Crawley et al. 2007; Winberg 2008). As an answer to the fourth research question, the results of this research indicate that applied technology research work can increase the engineering educators' knowledge and practical knowhow remarkably. However, the personal motivation of the educator has an impact on the knowledge increase. The educators found the applied research work as one of the best ways for professional development. They named several advantages of taking part in applied research. New experiences and personal development as well as interest in new technologies drove them to participate. At the same time the applied technology research was found to be very arduous. On the other hand, the educators found that harder work generated higher learning results. The role of applied technology research was seen as an effective way of lifelong learning.

All things considered, this research was essentially a discourse of interactions between HEIs and enterprises, especially small and medium sized enterprises. As a comprehensive answer to the research questions, the modelling of the actions and procedures have aimed at the interactions and collaboration that can add value for both sides. As a result of this research work the W^4 – a quadruple model for collaborative technology research activities between higher education institutions and industry – has been modelled. The purpose of the W^4 model is to create a WIN-WIN-WIN-WIN situation to the HEIs' regional innovation environment. The W^4 model fills the research gab recognised in the beginning of this research (European Commission 2011; Kautonen et al. 2015; Bradley et al. 2013; Davey et al. 2013; Leino and Laine 2014). When the HEIs and industry collaborate according to the model, all the participants, enterprises, HEIs, students and the surrounding society, win as the collaboration creates several advantages for all of them.

The W^4 - a quadruple model for collaborative technology research activities between higher education institutions and industry – describes how enterprises, HEIs and students bring their needs and knowledge to the shared platform of collaborative technology research activities and as a result of the activities they all gain something, something significant and meaningful. When the enterprises openly bring their technology needs and challenges to the process of collaborative activities, the HEIs can identify and allocate their expertise to these purposes and engage students to work in the processes.

The new knowledge of this doctoral thesis is crystallized in the W^4 model, which concludes the most important results of the research. The W^4 model is a new, more wide approach for the technology transfer combining the needs and knowledge of HEIs, enterprises and students but also the needs of the surrounding society called by Feller et al. (2002), Rauhala (2008), Tulkki (2008), Baaken and Schröder (2008), Žemaitis (2014) and especially Bradley et al. (2013).

The W^4 model shows how the HEI experts can identify the development needs of the enterprises and represent them in a structured mode that is easy to understand and use. At the same time, the HEIs increase their knowledge and understanding of SMEs' needs and challenges. The W^4 model represents that the technology knowledge search gives the enterprises focused facts and methods of new technologies and possible new ideas for the development, as well as helps the HEIs to find new knowledge sources and increase their knowledge of new technologies. When the students participate in the knowledge search, they can increase their knowledge of needed professional expertise and develop their up-to-date expertise. The W^4 model also shows that the applied research activities offer practical technology experiences with knowledge of possibilities, challenges and unfit applications to the enterprises as well as supports their investment and development planning. In the applied research work, the HEI experts increase their practical RDI engineering skills but also their knowledge of possibilities and obstacles of using certain technologies. At the same time, the real industrial engineering possibilities and experiences boost the professional development of students.

The W^4 model highlights impacts of the collaborative applied research in which the enterprises gain practical, but supplier-independent solutions for their problems as well as a deeper understanding of possibilities and obstacles of benefitting from certain technologies. At the same time, the collaborative innovation targeted research increases the HEI experts' knowledge of targeted open innovations and gives possibilities to identify best practices in order to model and develop the processes. Moreover, by taking part in real industrial RDI projects, the students foster their attraction, motivation and trust in new technologies.

The W^4 model proposes that the technology transfer and the interaction and conversations between enterprises, HEI experts and students assist the enterprises to reflect their ideas in order to foster future innovations and identify new business potentials. In wider partnerships, the HEIs can offer even more systematic help for the problem solving of the enterprises. Correspondingly, the better the HEIs know the SMEs and their needs and challenges the better they can answer the engineering education needs of the future.

One of the W^4 model's primary targets is to express the advantages of the collaborative research actions from different aspects of the enterprises, HEIs, students and society. In traditional, linear technology transfer the HEIs have carried out basic research and the enterprises have benefitted from the results by e.g. IP rights and licensing. In the W^4 model, the non-linear technology transfer is combined with several supportive methods and together they generate a circle of positive results, which foster each other. The HEI experts do the research work to meet the needs of the enterprises but at the same time, they increase their practical knowledge for the good of the education. The enterprises use the research results in innovation and business development in order to improve their growth but at the same time, they pay more taxes and produce useful goods for the society. The students bring their out-of-the-box thinking to research and help enterprises develop, simultaneously increasing their professional knowledge. That way they will be more competent professionals in the future and serve the society as productive citizens. The good results of the collaborative applied research followed by better learning experiences will improve the reputation of the HEIs and that way increase the funding for both research and education. These benefits of the W^4 model correspond well to the main target benefits of the HEI industry collaboration listed by Davey et al. (2013a). Davey et al. highlighted the improved employability of future graduates, the improved learning experience for students, the improved reputation in the field of research, the increased funding and the improved business performances. (Davey et al. 2013a)

At best, this virtuous circle rounds so that some of the benefits proceed straight to the society and some of them refine in enterprises, HEIs and among students and move then to the advantage of the society. In W^4 model's WIN-WIN-WIN-WIN situation, the enterprises evolve, the HEIs' research and education improve, the students graduate as competent professionals with regionally adequate knowledge and the society may enjoy all of this.

On an individual level of the HEI experts, the actions of W^4 can increase the meaningfulness of the education work and boost the self-esteem of the professionals. These may be significant factors in the lifelong coping at work but also on the emotional and productive level of a person. This thesis does not provide absolute statements for which are considered as the best engineering research or education methods. It concentrates on one working method that contributes to the quality of the engineering educators' professional development.

8.2 Validation of research findings

The research questions for this research have been formulated based on the recognised research gap during the years of empiric research of HEIs' RDI actions. Above all the research methods there were the constructive research methods influencing to the definitions of the research problems. The research frame was defined as a case study. The main variables of the research were the enterprises, the HEIs, the researchers, the technologies and the educators including all the teachers and lecturers.

This research has been fundamentally based on the constructive research approach, which has influenced the big picture but also all the research cases. The research has been constructive in its nature because it solved real world problems of enterprises and HEIs' with innovative models. However, the main research method in this thesis has been the design science research. The modelling of technology knowledge transfer as well as technology research, development and innovation within each project were based on design science research methodology. So, the validation of the research findings has been based on design science research methodology (Hevner et al. 2004; Hevner and Chatterjee 2010).

Following the design science research the validation is made through the guidelines itemised by Hevner et al. (Hevner et al. 2004; Hevner and Chatterjee 2010):

Design as an artefact

The goal of a design science research is to produce a feasible artefact, which can be a construct, a model or for example a method. In this research the goal of an artefact was achieved by combining the research results as the W^4 model. The W^4 model states the modes of collaborative technology research activities between enterprises, HEIs and students. The W^4 model is a comprehensive answer to the research questions.

Problem relevance

The problem relevance of a design science research can be validated by comparing the present state and the future state of the artefact and then by defining the relevance of the change between these states. The problem relevancy of this research was validated by comparing the traditional technology transfer methods and the future needs for more complex and non-linear ways for collaborative applied research. According to the literature review and the years of empiric research the relevancy of the problem is evident. The W^4 model enables the need based, innovation oriented and participatory research, development and innovation through open and non-linear actions. Compared to the traditional, linear technology transfer the W^4 model enables non-linear, more applied technology research and especially SME targeted collaboration. It also discloses all the additional profits gained by enterprises, HEIs, students and particularly the surrounding society.

Design evaluation

The evaluation of the design is based on the analysis of the artefact's usefulness, quality and/or effectiveness. The evaluation of the W^4 model design was performed experimentally based on the usefulness and effectiveness of the model. Each phase of the modelling was based on methodically planned true experiment cases and innovation. Then the utility, quality and effectiveness of the W^4 model was ensured by analysing the W^4 model and possible case paths that can be proceeded when following the model. In this analysis the different perspectives of HEIs, enterprises and students were taken into account. Also the advantages gained by the surrounding society were listed. The FIGURE 17 illustrates the case paths between the actors and the collaborative technology research activities.

Research contributions

Design science research must always provide a clear result like a new artefact, new knowledge and/or a novel method. The main contribution of this research, the W4 – a quadruple model for collaborative technology research activities between higher education institutions and industry, is a clear, novel and useful model that answers to the needs and questions set in the beginning of this research.

Research rigor

Design science research relies on the rigorous construction and evaluation methods used in the research work. The rigorous of this research was validated by following the chosen research methods, and by combining the research methods in order to find the deeper meanings and results for the use of the modelling.

Design as a search process

The design science research process is a knowledge search process where useful and available methods are used to find requisite information needed to accomplish a solution as practical as possible (Hevner et al. 2004). In this research the model design process itself was a knowledge search process where necessary methods were combined to design a practical model for collaborative technology research activities between higher education institutions and industry. In the execution of the cases the design science research method was found a very useful method in applying the technologies and in best practice identification the case study research method generated meaningful parts for the modelling.

Communication of research

After the design science research process, it is essential to introduce all the significant knowledge of the design work to both technology-oriented and management-oriented groups of interest. In this research the individual cases and knowledge acquired in them were closely introduced to both case related engineers and managers. In bigger picture this thesis acts as one of the main communication methods of this research. Also the peer reviewed papers and the conference presentations worked as good communication methods.

As a result of the research validation it can be confirmed that all the phases of this research have followed the design science research method and the results are valid.

Contribution to science

This research has several stages of contribution. The main contributions to Science come forth in the technology research cases where the results validate the scientific value of the technologies but also in the new, multipurpose knowledge of HEI-SME technology transfer.

Contribution to practice

The contribution to practice has a clearly larger role in this research. The main contribution to practice is the W^4 model that constructs a distinct and directional structure of innovation environment for the use of HEIs. It makes the activities and advantages visible and that way highlights the role of HEI-SME collaboration in innovation. In addition to the W^4 model this research contributed in the details. The partnership process model guides the HEIs in partnership practicalities. Moreover, the three different models of technology transfer offer the HEIs tools for arranging and benefitting of technology transfer. In addition to these this research also contributed significant knowledge of research work as a part of the professional development of engineering educators. This knowledge can be used especially in encouraging of the educators when considering of participating in research work.

8.3 Strengths and limitations of the research

This research has several strengths. The research material was wide, like dozens of cases and actors. This way the different factors, phenomena and impacts could be identified. The models created in this research are pragmatic but have implications to both theory and practise. The models can be utilised highly in the management and creation of innovations in collaboration between the higher education and industry. The modelling is a generalisation since it is a simplified description of reality and the research tried to capture the most essential parts of the phenomena. The results can be generalised to similar environments and organisations, yet they should be used with care because the initial conditions also affect the results that can be achieved.

There are some limitations in this research. The modelling is done for the collaboration between SMEs and HEIs, especially UASs and their networks. There may be differences between SMEs. Like, some enterprises are more entrepreneurial and have more positive and pragmatic approach towards new product, service and process development. The models fit for these SMEs. Also, the collaboration took place in two regions in one country. And, the research was done in these certain fields of technology (automation technologies and well-being enhancing technologies) and with existing enterprises in quite traditional fields of industry. There is no proof of how the process would work with dynamic start-ups, for example. Therefore, the models must be applied in context.

8.4 Future research work

The W^4 - a quadruple model for collaborative technology research activities between higher education institutions and industry – is designed and modelled for HEIs, which have strategic ambitions to work in close collaboration with the enterprises of the region, especially the SMEs. This research indicates that despite strong basic research all HEIs should allocate at least part of their research actions to need based research implemented based on the W^4 model. This model is also a good starting point for the HEIs looking for strategic changes towards more collaborative research. The model opens new possibilities for shared collaborative applied research between HEIs and their enterprise networks. That way the HEIs can complete the knowledge selection of each other. Together HEIs can serve more enterprises simultaneously or offer such knowledge that a single HEI or a HEI from a certain region cannot offer.

In the future a prominent question will be: how should these HEIs network in a reasonable manner? It is important to network in order to know the key knowledge areas of the partner HEIs but there is no need for networking only because of networking. The networking should be smart and generate practical and visible advantages.

Another question for the future will be: How should this way of thinking trough the W^4 model be marketed to actors, like other HEIs, enterprises and students? And how should the model be introduced to the decision-makers who decide funding for the research projects?

The third question for the future is: How should the W^4 model be tested? Different HEIs can benefit from the model differently. How can the benefits be recognised and compared even-handedly? Particularly, when the W^4 model has potential to evolve in the use of other universities, who modify it to better answer their regional and focus area bounded individual needs. At the same time, they bring additional value to the model by applying it to different fields of research or business. In addition, the other existing collaboration models can be modified by the W^4 model while the diversity and the practical implications of the model evidence the versatile and simultaneous benefits of it. Overall, the W^4 model ensures that the research knowledge of the universities is exploited as the innovation resources of the economic life. Meanwhile the universities can ensure the up-to-date knowledge of the students and educators in the most natural way.

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ORIGINAL PAPERS

I

UNIVERSITY INDUSTRY INTERACTION

BEST PRACTICE MODEL FOR PARTNERSHIP

by

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Conference Proceedings of the 13th International Science-to-Business Marketing Conference on Cross Organizational Value Creation

University Industry Interaction
Best Practice Model for Partnership

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Abstract
Satakunta University of Applied Sciences (Satakunta UAS) has developed multiform interaction with the local industry for years. This interaction has evolved into partnerships with some of the firms. Typically these firms are significant operators in their field of industry. Partnerships are continuously developing processes, and the creation of trust is a crucial part of them. The trust between the university and firms grows with small and specific action steps. One well tried way in promoting the trust is to focus on the firm's Research, Development and Innovation (RDI) actions. In these kinds of university-industry partnerships the research, development and innovation needs of the firms are constantly identified and, based on the identification, the most potential development tasks are defined and prioritized. This persistent work creates a solid base for a developing RDI co-operation. The partnership board is an essential operator in this identification process while students are the main operators in the implementation of the tasks.

In the paper the partnership based RDI process is modelled. The model is described and evaluated with case examples from the students' point of view. The model is based on student projects, theses, work placements and technology evaluating processes performed by the students and guided by the expert lecturers but also on more demanding research projects conducted by the researchers. In the paper, e.g., the processes evaluating technologies are illustrated with case examples. When the evaluation process has been divided into smaller sections, every group of 2-4 students can be absorbed in evaluating one technology. In this way every technological possibility receives the attention it deserves and the results are practical and meaningful. This kind of evaluating process gives the firms wider and supplier independent information of the potential technologies for the improvement of the target. At the same time the students receive subjective experience of real-life RDI cases.

As the main outcome of this research a general best practice model of the partnership between a university and industry is created and evaluated.

Keywords
University, Industry, Interaction, Best Practice, Model, Cases

1 Introduction

This paper concentrates on partnerships between a university and industry in the creation of innovations in a regional context. Satakunta University of Applied Sciences (UAS) in Finland is used as a source for the case study to model the partnership interaction. The research aims at creating a best practice process model of partnership in a local context. The model should be pragmatic and have practical implications. There will be many potential benefits of using the model for both industry and higher education.

In order to develop and broaden the partnership actions the partnership process needs to be modelled. Then new operators can benefit from lessons learned from earlier actions and there is no need to reinvent the process and practices. The modelling is done for shareholders, partners and potential partners. It can be used to better understand and develop actions.

The structure of the paper is the following. First the background and theories are explained. Then the Satakunta UAS partnership process is modelled and the main actions of partnership model are presented with case examples. This is followed by the evaluation of the partnership model with best practice identification. The main results are summarized and discussed, and conclusions are given.

2 Background and theoretical framework

In the knowledge-driven economy there is a growing need for deeper and more productive interaction between higher education and industry. The full exploitation of knowledge requires strategies, incentives, appropriate processes and a strong interaction between the transferring processes and the main processes in the higher education. In a knowledge-based economy, knowledge is more likely to be created in application collaboration. In this kind of knowledge creation process, the knowledge creation, dissemination and utilization are carried out close to each other or even simultaneously. In addition, basic research and applied research can no longer be separated. Knowledge creation is discovered to be, in many cases, based on a long-term partnership where trust, commitment and mutual benefit can be achieved. (Laine 2010.)

Modelling of partnerships in this research focuses on processes which aim at the creation of innovations by creating new valuable combinations of internal and external knowledge. The research will use mixed methods by combining qualitative and supporting quantitative methods and process modelling. Innovation management research typically models the development paths of the idea, the people and organizations involved in the interactions and the transactions between the operators, the outcomes of the innovation process, and the context of innovation. Although innovation paths are individual, general elements suitable for most similar processes are presumably discovered (Tidd et al. 2005, Van de Ven et al. 2008).

In this paper a partnership is defined as long lasting collaboration between organizations in order to solve strategic challenges. A model is defined as a simple description of a system to describe how it works and to show its essential elements. Evaluation is judging the value or the condition of (someone or something) in a careful and thoughtful way (Merriam-Webster dictionary). A process is defined as a series of actions that are performed in order to achieve a particular result.

Best practice is a method or technique that has consistently shown results superior to those achieved by other means, and that is used as a benchmark. Best practice can evolve to become even better as improvements are discovered. Best practices are used to maintain quality as an alternative to standards and can be based on self-assessment or benchmarking. Best practice can be used to develop and unify practices, learn from them and to share practices with others.

Innovation is the implementation of a new or significantly improved product (good or service), or a process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations.

In Finland the main drivers of University Business Collaboration (UBC) are mutual trust, short geographical distance, prior relation to the business partner, mutual commitment and a common interest of the stakeholders. The main benefits of UBC identified by Finnish academics are: improved employability of future graduates, improved learning experience for students, improved reputation in the field of research, increased funding and the improved performance of a business. The main barriers to UBC in Finland have proven to be: differing time horizons between a university and a business, the limited absorption capacity of SMEs to engage work placements or projects, the businesses lacking the awareness of the university research activities/offerings, the lack of financial resources of the business and the lack of university funding for UBC. The main benefits of UBC have been identified by the representatives of the Finnish HEI (Higher Education Institutions). According to them, UBC is seen vital in achieving the mission of the university, in improving the skills and graduate development. Furthermore, UBC has beneficial effects on the local industry, it increases local GDP and disposable income, and it creates local employment. Supporting mechanisms may be strategies, structures, approaches and activities. In Finland it is typical to have documented strategies with implementation plans. Collaboration is role-based and there are internal and external agencies focusing on it. Activities are, e.g. workshops for academics and students, networking, and promotional and project activities. (Davey et al. 2013.)

There are several reasons for developing interaction between higher education and industry. Practices change. It has been noted that collaboration matters. However, new ways to collaborate are searched. There is a need for more operative and goal focused collaboration between HEIs and industry. Earlier, industry was curious and wanted to see if collaboration had something for them. Nowadays there is no longer time for these kinds of open ended processes. Industry wants to define what they want as output and outcomes from the collaboration, and this definition steers collaboration. Our assumption is that HEIs should set their own goals as well and clarify them in the beginning of collaboration to avoid confusion and mistakes in collaboration.

2.1 Creating trust

Trust in relationships is a complex issue. It can be on a personal, team or organizational level. There are also dynamics between personal and organizational levels. Several researches have focused on trust, mainly on people’s conceptions of trust. Fewer researches have explored how trust is created in collaboration and what kinds of actions create trust. Partnerships between universities and firms are asymmetric from the knowledge point of view.

The creation of trust is necessary before the networked partners are willing to share knowledge openly and spontaneously. Trust is comprised of three dimensions: competence, goodwill, and identity. Competence is the most important element of trust (Blomqvist 2007, 178-190). Trust can be created by immediate problem-solving, frequent contact, honest communication and by developing wide relationships (Wilson and Wilson 1994). In dynamic situations entrepreneurs use fast personal trust based on fact analysis and intuition (Blomqvist, K. 2007, 178-190). Collaboration competence is seen as a core competence for innovation (Blomqvist and Levy 2006, Miles et al. 2005, 2006). In the future, the success of innovative SMEs is based on technology and trust (Miles and Snow 2005, Miles et al. 2005, Laine 2010).

Time, trust and territory are needed before the creation and transfer of knowledge can happen in innovation collaboration (Miles et al. 2000). Territory here refers to the personal areas of knowledge that are identified and accepted. Lewicki and Bunker (1996) separate trust into three levels: calculated trust, knowledge-based trust and identification-based trust. Transitions to a higher level of trust can happen in time. Predictability creates trust and predictability is created by sustained social relations. (Lewicki and Bunker 1996, Bews and Martins 2002.)

Calculus-based trust is based on a hope that positive actions will be rewarded and the fear that negative actions will be punished. Lewicki and Bunker (1996, p. 120) point out "…that at this stage, the deterrence elements will be a more dominant 'motivator' than the benefit-seeking elements". Knowledge-based trust rests on predictability which is, in turn, based on knowledge gathered during regular interactions (Lewicki & Bunker, 1996). At this stage even negative outcomes can be tolerated. Identification-based trust is a form of trust dependent on a deep understanding of the needs of another and an "...identification with the other's desires and intentions ... to the point that each can effectively act for the other" (Lewicki & Bunker, 1996, p. 122). Identification-based trust is a form of trust where one party will protect and promote the interests of another. At this level, trust is usually seen in more intense relationships. Contracts are typically minimal at this level. (Robbins, 2001).

3 Satakunta UAS partnership process

Satakunta University of Applied Sciences is a horizontal, internationally oriented university with 5 650 students and 400 experts in 28 Finnish and 5 English programs. Offering both Bachelor and Master level education as youth education as well as further education for adults, SAMK has a wide contact surface for the employment sector both nationally and internationally. The faculties are: Welfare, Health, Service Business, Logistics and Maritime Technology, Energy and Construction, and Information Technology.

SAMK is the leading institution of higher education in the Satakunta region, operating on the west coast of Finland. SAMK is a limited liability company owned by the regional municipalities and local business institutions and organizations. Through the public non-profit status and responsibility for regional development set by The Ministry of Education, SAMK is conducting public interest collaboration between higher education institutions, research and development (RD) centers and business sector.

Cluster development, networking and knowledge management activities have led to partnerships with the most active network contacts. The same model can be used with private and public organizations and clusters. Partnerships are future-oriented collaborations that use several elements of the interaction model to benefit both parties. (Laine 2007, 2008) The main features of the partnerships are the following: The partnership starts with a meeting with the senior management and strategy-level thinking of the goals. Both acute and future needs of partners are covered. The time frame for partnerships is several years. Partnerships are based on a contract with a list of contact people, milestones and responsibilities for actions. Theses and student projects are some of the tools that are used in knowledge creation. R&D&I project activation is also included. Third party funded projects are an option. Direct contract projects are a part of activities.

Satakunta UAS started partnerships with several types of organizations a few years ago. These organizations were large enterprises, SMEs and public organizations. In the beginning there were no clear goals for the partnerships, but there was the presumption that partnerships would create long lasting, deeper and more beneficial and flexible collaboration than ad hoc collaboration relationships. Another goal was to centre most of the connections on one contact person per partner to avoid ad hoc contacting. Ad hoc contacting tends to confuse partner organizations because the same type of contacts may come simultaneously from several people. This paper focuses on two partnerships, with Pori Energia (a local energy company) and Oras Oy (a local faucet and shower manufacturing company).

Collaboration in the partnership can have several forms, e.g. adaptive work placements, technology demonstrations, focused visits, Research and Development seminars, projects by students and personnel, theses and continuous personal development. All these can be used to fulfill the need of the partner. A partnership should be productive.

3.2 Partnership process model

Partnership establishing consists of five phases: identification of potential partners, partnership contract, partnership board, collaboration and evaluation. The partnership process model is presented in Figure 1.

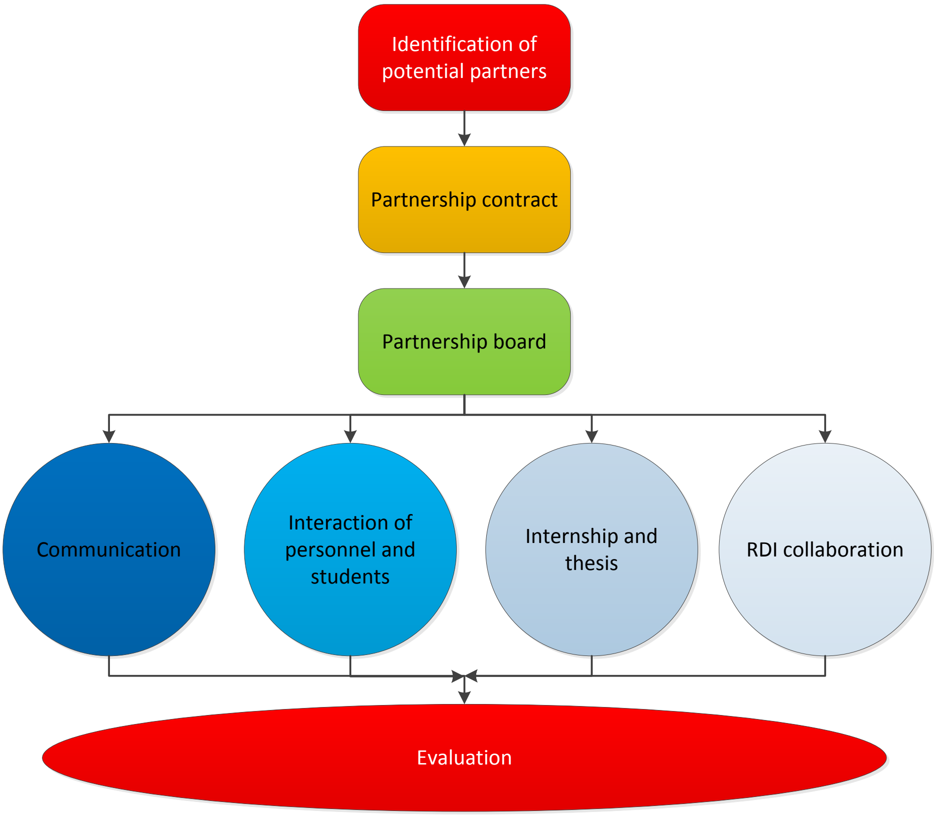

Figure 1. Partnership process model.

3.2.1 Identification of potential partners

Partnership identification is a continuous process pursued by university employees interested in collaboration with partners. At the same time, the existing partners may spread good results of the partnership to their networks and a new firm may become interested in a partnership with the university. When a potential partner is identified or has volunteered, the preliminary or pre-contract partner work is initiated by the responsible university manager.

3.2.2 Partnership contract

The university has a formal template for the partnership contract. This template is used to create a contract that satisfies both parties. The contract defines the main objectives for the partnership and the essential actions to achieve them. Significant parts of the contract are the confidentiality agreement, ownership rights and rights to use the material produced in the partnership as well as the agreements of costs, the partnership board and the cancellation of the contract.

3.2.3 Partnership board

The partnership board has a very significant role in partnerships. The board is nominated in the partnership contract but it may be established at any phase of the partnership or the appointed persons may be changed when needed. The partnership board meets a couple of times per year and every time all the main actions and their status are evaluated. All the new subjects like new theses, new development projects and adaptive work placements are brought to the board meetings and the board decides which of them will be started. Also the results and possible challenges of the actions are discussed and considered from different viewpoints by the board.

3.2.4 Collaboration

The partnership board coordinates the collaboration as an entity. The collaboration consists of:

- Communication
- Interaction of personnel and students
- Work placements and theses
- Research, development and innovation projects

The board reviews new ideas, selects ideas for implementation, starts the planning of the actions, reviews the plans, evaluates actions and results. In addition, the board attends to the implementation challenges that could not be solved.

3.2.5 Communication

Communication between partners is perceived as one of the key actions in partnerships. Without proper and systematic communication the planned actions will not work as anticipated. Communication between partners and external networks is also important especially when results and achievements should be presented or when new collaborative projects are starting. Communication is set as one of the main subjects on partnership board meeting agenda. Consequently all communicative issues will be discussed and planned when needed.

3.2.6 Interaction of personnel and students

Supporting the training planning and the execution of the plans is included in the partnership. Good examples of partner interaction are different kinds of trainings that can be arranged so that the personnel from both the partner organization and Satakunta UAS participate together and the costs will be shared. Recruitment info and company excursions for students can be arranged so that the personnel of UAS and the students become familiar with the partner firm. Additional tested collaborative activities are, e.g. seminars and personnel work placements.

3.2.7 Work placement and thesis

From the university point of view the work placements and Theses are the two most important outcomes of the partnership. Different kinds of work placement methods and thesis subjects are constantly planned and discussed in the board meetings.

3.2.8 Research, Development and Innovation collaboration

Research, development and innovation (RDI) collaboration is one well tried way in creating trust but it also requires trust. Therefore, it should be started with small steps in the beginning of the partnership. When the first steps of creating trust are taken, the identification of RDI challenges may be started. The first identification is done by listing the acute development needs of the partner firm. The development needs are operationalized by transforming them into practical actions like measurements and searching of technology knowledge. Both the identified needs and practical actions are then prioritized according to the importance, urgency and available research knowledge and resources.

The prioritized list of development needs and actions is documented so that it can be used as a checklist during the process. Following this list the development actions are planned and described in more detail. Some development cases may be very quick in the right hands of accomplished personnel but some cases may need longer time periods and also knowledge from other sources. Planned RDI collaboration consists of different operative actions like theses, student projects and more demanding research projects conducted by university researchers and project engineers. Scheduling of all the actions is a part of the checklist writing.

Resources for the RDI actions are allocated case-specifically. The partnership contract does not allocate any resources for RDI collaboration but all the actions will be planned case by case with separate budgets and financing programme. When all the plans have been formulated the actions are carried out according to them. When new challenges are met the project personnel tries to solve them with the help of the firm's personnel. Challenges exceeding the scope of action plans are discussed in the partnership board.

3.2.9 Evaluation

Regular review and the evaluation of actions take place usually twice a year. The evaluation is based on the objectives defined on the planning phase, on process resources and results. (Lähdeniemi et al. 2012, Malinen et al. 2009, Leino 2009).

3.3 Action steps for creating trust

In the partnerships between Satakunta UAS and local firms trust is created with small specific action steps

- › Showing curiosity towards real world problems
- › Constant identification of new problems
- › Versatile evaluation and prioritizing of problems

- Systematic verification of competences
- Problem-solving based on knowledge and systematic approach
- Collaborative learning

All these steps are seen in partnership meetings. Typically, all real world problem-solving requires diversified knowledge. Therefore, the partnership board should consist of people from several various fields of industry, education and research.

4 Case examples of partnership actions

In this chapter the modelled actions of the partnership based cooperation are described with several case examples. Adaptive work placements, projects for evaluating technology as well as more demanding research projects and thesis works have been chosen for examples presented here.

4.4 Adaptive work placement

Adaptive work placement is an operations model that has been developed to serve both the company and the university and its students. Adaptive work placement starts with student selection. The company observes students in their summer jobs and chooses yearly a couple of developable students to adaptive work placement. This gives these students opportunities to work in the same company in different positions throughout their studies. They see many different duties and have the chance to apply the theories learned in the university into practice, in their workplaces.

For the companies, adaptive work placement is a very effective way to get skilled employees who know the company procedures without hard orientation processes. It also gives the students a diverse possibility to identify their own interests. When a student has worked in the company for many periods of time per year over two to three years it is quite easy to find an interesting and meaningful topic for the thesis. This is a productive starting point for a thesis and usually leads to a quick graduation.

It is very important for both the company and the student to remember that although the students are chosen to adaptive work placements with a view to employment opportunity after graduation, it is not self-evident. The student must earn each subsequent work placement with hard work and by developing their know-how. After the graduation the student has a chance to become employed if there is a suitable open vacancy in the company.

4.5 Student projects for evaluating technologies

Good examples of cooperative RDI actions performed by the students are the projects for evaluating technologies. Both the students and the firms find these kinds of projects very productive. Two examples of such projects are described below.

4.5.10 Evaluating technologies for package quality purposes for Oras

This case example describes a project of technology evaluation made by engineering students for the partner company Oras Oy. Oras is planning on improving the packaging quality of their products. The main purpose was to construct an automatic system to verify the package validity. The preliminary study illustrated that there are many potential technologies that could be used. Based on these findings it was decided that a project to evaluate technologies was to be executed to support the decision making process.

This project was designed to be realized as five subprojects. Every subproject evaluated one technology and was assigned to one group of students. Each group performed their work as a part of either a course on machine vision or a course of a machine automation project. The evaluated technologies were

› Radio Frequency Identification (RFID)

› Automated scale based identification

› Color packaging based machine vision identification

› Shaped packaging based machine vision identification

› Sample based machine vision identification

Each subproject group built a requisite setup for testing. They ran the tests with real packages with effected quality deviations. According to the tests the students programmed functioning software for the purposes and tested again the functionality of the systems. The evaluation tests were graphically documented and the usable and impossible technologies were listed for the use of the company's decision making process.

4.5.11 Led street lighting project for Pori Energia

Pori Energia, another partner company of SAMK, is planning on changing street lighting technology used on the streets of Pori. LED street lighting is one possibility and that is why they asked SAMK students to execute a project of evaluating technology of LED street lighting. In this project the students tested LED street lighting in SAMK electrical engineering laboratory and in a real life environment in the district of Nyrkkilänpuisto. The aim of this research was to test the consumption of electrical energy with different kinds of light sources, to observe power quality and to measure the intensity of lighting with different sources.

The students also interviewed the residents of Nyrkkilänpuisto in order to collect their opinions on LED lighting in use. The results of this project of evaluating technology will be used in the decision making process in Pori Energia. This student project was also rewarded with a grant from Federation of Special Service and Clerical Employees, ERTO.

In addition to the obvious benefits for the company, this kind of projects for evaluating technologies give the students deeper know-how of certain technologies and a clearer understanding of projects and cooperation in projects. At the same time the students also learn researcher-like manners in evaluating technology. When the students take the responsibility of the evaluation process they force themselves to investigate and find the right action steps and that way to identify the fruitful ways to seek for answers.

4.6 Research projects - students developing into research engineers in the university

Another method in university industry partnerships are the deeper research projects conducted by university researchers and research engineers. Usually these kinds of projects commence through the identifying and evaluation process of RDI actions in the company. The need of the research project rises from the company and its developing targets. University researchers and research engineers take the responsibility of the research actions but they also include a couple of engineering students to participate in the research. In this way these students become acquainted with the basic research steps and learn how to work with researchers.

4.6.11.1 Thermal Imaging Research in Optimizing Sand Core Production – Case Oras

Oras, a local, big faucet producer, needed help in improving their production and especially one of their sand core producing cells. The sand cores were not homogenous and a large number of cores were broken before they could be used in casting. SAMK researchers together with one automation engineering student started a thermal imaging research with an objective to find and solve the problem. Thermal imaging research of the process revealed clear faults in some of the heating elements. With three improving steps of the heating elements and thermal imaging after each step the heating elements were developed so that the thermal distribution was as homogenous as possible. The research was the key to successful improvements.

From the engineering student's point of view this research project was a diverse learning experience. He underwent all the main phases of a research project, learned thermal imaging in practice and how to document research points and results. While the student had an important role in operative tasks of the project he also learned how to work in a university research project. This way he evolved into a skillful research engineer and was and still is employed by the university.

4.7 Theses

Students in adaptive work placements are encouraged to find their thesis topics by themselves while working in different positions in partner companies. This is noticed to be a very productive way in topic identifying. When students find their thesis topics by themselves they are very involved with the work from the beginning. They also finalize their theses with great results and on time.

The partner companies have also had many theses done by other students. In these cases the topics for the studies are brought to the partnership board meeting and from there to expert lecturers who find suitable students to perform the studies. The expert lecturers have a great responsibility in finding skilled and motivated students for specific theses.

In partnerships with Pori Energia and Oras **SAMK the students** have finished in total over 50 theses in less than six years. The partnerships have helped SAMK and the companies to find more systematic and organized ways to commission theses. When the partners know each other and have mutual trust it is easier to bring subjects on the table. On the other hand the topics are easier to discover and the search for a thesis student is more straightforward.

5 Evaluation of the partnership model

In this chapter all phases of the partnership process are evaluated and best practices are identified. The main goal of a partnership is to create practical results.

Table 1. Evaluation and best practices of the partnership process.

Partnership process phase	**Evaluation of the phase**	**Best practices identified**
Identification of partners	Active identification, different types of partners, contacts based on partners' recommendations	Openness to all types of partners and partnerships
Partnership contract	Formal, simple general template, partner-based details, commitment of senior management	All key actors involved, shared understanding of importance and trust, contact person of the university selected
Partnership board	Role of the contact person is remarkable, all voices are heard, equal partners with equal authority, well documented meetings, all ideas, plans and actions covered	Covers everything but not in detail, future-oriented approach
Collaboration	Several simultaneous actions and communication, role of a student is emphasized, only part of the partners want to include RDI collaboration	Type of collaboration based on needs, opportunities for students to participate in different types of tasks, step by step creation of trust based on collaboration, time scales and actions agreed, concrete results
Evaluation	Continuous, informal, learning centered, UAS actively asking for feedback, made by the board, a lot of learning outcomes from university processes	Evaluation on agenda in all meetings, reporting results into the university metric systems for maximum benefits

Evaluation is actually conducted in board meetings, not as a separate action. This ensures constant feedback and the evaluation is done when actions are still in the fresh memory. The university contact person collects feedback from students and teachers and the contact person of the partner organization from his/her organization. The evaluation is based on

- The quality of planning
- The quality of actions
- The quality of process and resources
- Achievements reflected on goals, amount and quality
- The management of actions
- Communication and publications done based on partnership
- Interaction in partnership
- The scope of partnership

All above issues are covered in an unofficial manner during partnership meetings. The meetings are documented and the documents or parts of them are distributed to all people involved.

6 Main findings and discussion

The main result of this research is the partnership process model presented in Figure 1, the evaluation of its phases and the identification of best practices in all phases presented in Table 1.

The process is described as linear. When the board is nominated and parallel actions start, the actions may not look as simple as the description. The coordination of actions is a demanding task for the coordinator. The quality of partnership and its development seems to personified to the coordinator.

According to the research, all partnerships are different but similar process phases and elements can be found in each of them. The same phenomenon was observed also in innovation management research. Identifying the related and complementary knowledge areas of the partners is a very important step which leads to the next level of the partnership.

In this research, creating trust is considered as one important factor of successful partnership. This research shows that both knowledge-based trust and identification-based trust are usual in these kinds of partnerships between a university and industry. The research also indicates that the sooner the transition from knowledge-based trust to the identification-based trust happens the sooner the partnership gets on a more detailed level of collaboration. Identification-based trust makes it possible to deeply know the processes and products as well as their problems for the partner. Consequently, the results of the partnership may be remarkable.

One essential question for the future is how to develop the process so that the university is actively setting goals already in the beginning of the process to ensure actions that create the needed results for the university. This should lead to maximizing the wanted results and metrics set for universities.

A sign that shows that the network is actually developing is that its members create new practices together. In partnership this should happen in a similar way. In the researched cases this seems to be true. Partnerships based on contracts that are organization-specific seem to develop to their own directions. The development of a partnership is personified to the partnership coordinator. Therefore, it is important to find more committed people from the university side to coordinate the partnerships. Otherwise it is not possible to increase further the number of partnerships. Partnerships help developing the competences needed in partner organizations. A coordinator of a researched partnership said:

> *"Nowadays all my new competences are based on needs of partners."*

The role of students is emphasized. A lot of students have participated in different roles. The same students can also have several different roles in the same partnership during several years. The students give the university a lot of feedback that can be used to develop processes. They seem to be very satisfied with the learning outcomes they have attained in different projects. Also the adaptive work placement receives a lot of positive feedback. The students praise especially the wide range of different working experiences.

Partner organizations are satisfied with the amount and type of actions, systematic problem solving approach, the research knowledge based on their own process data, and the documentation of the results. As a partner organization representative stated in a board meeting:

> *"It is easy to make decisions now because we have true knowledge based on measuring data."*

The partnerships have helped the partners to solve several problems, create new products and services and to make investment decisions based on knowledge.

7 Conclusions and recommendations

In this research the partnership process between the university and industry was described and evaluated. According to the findings, it is important for partnerships to understand the importance of trust and of creating trust, to make clear goals for the partnership, to agree on operational actions, to perceive time scales, and to create concrete results with mutual benefits for university and industry. The role of students is emphasized in partnerships. Both the university personnel and the students and the personnel of the partner firm seem to learn a lot in the collaborative actions made in partnerships.

There are several benefits, e.g. new learning outcomes and the need-based competence development of personnel. However, partnerships require constant development of the process and the actions. A lot of feedback concerning university processes is available.

Partnerships create research-based knowledge to support innovation process in industry, foster new innovation creation and open eyes to see new opportunities for future collaboration. It is recommended that higher education sets its own goals from its own point of view and sets the goals already in the beginning of the process.

The research has implications both for theory and practice. The created models can be utilized in the management of partnerships and in the creation of innovations in collaboration between the higher education and industry. The modelling is a generalization since it is a simplified description of reality and the research tried to capture the most essential parts of the phenomenon. The research was found to have several practical implications. The results can be generalized to similar environments and organizations, yet should be used with care because the initial conditions also affect the results that can be achieved.

The study suggests future research items, such as how to build a network of partner organizations with even more innovation potential.

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II

COGNITIVE MOBILE GAMES FOR MEMORY IMPAIRED OLDER ADULTS

by

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Cognitive mobile games for memory impaired older adults

Structured Abstract:

Purpose
Cognitive self-rehabilitation lacks updated means and tools. The purpose of this study was to evaluate the effect of cognitively simulating mobile games on the cognitive skills and recreation of older people with memory impairment.
Design/methodology/approach
Mobile games that require cognitive skills were developed. The games were played by memory impaired older adults with an average age of 90. Gaming trials took place over three months with game play occurring on a daily basis. Game outcomes were automatically recorded and user feedback was collected by interviews. The progress of the testees was also evaluated by means of Trail Making Test A.
Findings
Improvement in game scores was found. Other significant effects of game play were enhanced recreation and self-managed activity level. Game play did not have any effect on the traditional Trail Making Test -results but the results of the Trail Making -game showed improvement. The Trail Making -game also showed a large variance in daily scores, which implies that performing just a single Trail Making Test might lead to misreading a person's condition.
Research limitations/implications
The results are an encouragement for conducting further testing (on a larger test group, over a longer time) and continuing with game development for cognitively impaired older adults. A similar game trial will also be arranged for a younger population with better overall health condition.
Practical implications
New business opportunities are also possible in game development and gaming services.
Social implications
Games have the potential for self-rehabilitation and to support extending independent living at home.
Originality/value
The paper provides a synopsis of novel cognitive recreation tools, an analysis of their effect and user feedback from professional staff as well as potential new ideas for game developers.

Keywords: Mobile game; cognitive impairment; older adults; recreation; self-managed rehabilitation

Article Classification: Research paper

1. Introduction

Memory disorders are one of the most significant groups of diseases requiring health and social services support and intervention. Memory disorders present physical, psychological and cognitive challenges. Despite impairments of physical functions, cognitive challenges appear as impairment to observation, attention, working memory, processing speed, dual tasking, coordination and visuospatial conceptualisation. [5,24,27,31] Memory disorders become increasingly common with the aging of the population and lead to progression of disabilities, the need for constant assistance and ultimate dependency on institutionalised care [1,31]. Good care of degenerative memory diseases consists of providing appropriate medication and timely support services including physical activity and individualised rehabilitation that has been proven to slow down the progression of the memory diseases [2,3,4,24,27,28,31]. Research findings confirm that the lowest cognitive and physical activity levels correspond directly to the risk level of Alzheimer's disease morbidity [7].

Due to the ageing of European societies, increased attention has been paid to generating of new innovative methods in care, general health and rehabilitation of the aged where the client is less dependent on professionals [22,25, 26,31]. Activation in this paper is defined as proactive measures or services enabling people to self-manage their health problems, engaging in activities that maintain functioning and reduce health declines, as well as being involved in decision making related to their own health. In literature the term is oftentimes presented as Patient Activation [46,47] referring to the same thing but in clinical settings. Even older adults in most cases have some degree of chronic health issues, in this paper term patient is not used in relation to activation in order to avoid labelling aging as medical problem. Self-management in activating oneself, remaining active, and taking more responsibility of one's own general health condition and rehabilitation could therefore offer some solution to the problem where a person is empowered to take charge of maintaining and even restoring their own health status by means of controlled rehabilitation events. Self-management in activation and rehabilitation requires knowledge but also new motivating, easy-to-use and safe methods and tools to facilitate performance [30,47]. The most successful new tools seem to consist of two important factors: entertainment (self -motivation) and relevant therapeutic content (rehabilitation) [23,24,27,36]. The goal of this paper is to investigate two mobile games generated for older people with memory impairment as potential self-managed rehabilitation tools, and to measure the possible effects of mobile games on their cognitive skills (rehabilitation) and motivation (entertainment, meaningfulness).

Findings from scientific research studies show that, in general, playing video games can lead to changes in an individual's pleasure, alertness, dominance, and therefore in the state of experienced well-being [1,8,28,32,37]. Also in the case of older adults, video games, which are simple and easy to play, are more easily accepted and found to create positive feelings and enjoyment [9,10,23,31,36].

In this study, the games were generated for touch screen mobile devices with an acceleration sensor (smart phone or tablet pc). Smartphones with touch screen-based interfaces are increasingly used by non-technical groups including the elderly. Previous studies indicate the suitability of touch screen technology in serious games. Mobile touch screens are found to be generally easy for the elderly to use and even a small amount of experience generally improves their proficiency. [38,39,41]

We wanted to generate one game that combines physical movement and cognitive stimuli. Playing the game would require coordination of hands and brain by means of light physical exercise. This approach is based on studies showing that both physical exercise and game play have positive effects on older adults [27,28,33]. Moderate, regular exercise may be just as helpful in combating serious depression in older people as antidepressant medication [6,29]. It is also known that acute cognitive benefits, such as temporary improvements in concentration, can result from as little as ten minutes of exercise [11,31].

The other game investigated in this study is based on the traditional Trail Making Test, which is used for assessing/detecting several types of cognitive impairments. The game is a modified interactive version of the traditional pen and paper Trail Making Test A [12,40]. The secondary purpose of the Trail Making game was to evaluate the performance and progress of test persons, and the possible comparability in results with the traditional (pen and paper) type testing which was used as comparative data in evaluating the game trials.

Usability was taken into special account during game design. Since the games were intended for people not necessarily having any technical background or experience, the game applications were designed to be as simple as possible on a tablet PC. Also the player identification was automated by embedded near field communication (NFC) technology [13]. Subjective user experiences were collected by semi-structured interviews of players and direct observation of the staff.

This research studied the usability of game technology in self-management, activation and rehabilitation among older adults with slight memory impairments. The aim of the study was to find out the applicability of cognitively stimulating mobile games in order to improve or maintain the attention and memory abilities of older people. In addition, this study focused on collecting and analysing older adults' experiences about the games and evaluating touch-screen tablets as a means of gaming interaction.

2. Game platform and the rehabilitation games

Commercial mobile games are typically fast-paced, rich in visualisations and other effects, and are targeted for gaming-oriented user groups who are familiar with handling various devices and are well used to performing complex commands. In this study, the game platform does not require any special game consoles. The game graphics are simple; the game intensity and challenge levels are adjusted accordingly for the target user group. When designing the games, the research group actively collected feedback from the target group regarding the overall design and other playability factors. The words simple and plain were repeatedly mentioned. Therefore the graphics and controls were kept simple, avoiding demanding animations or back ground effects which would blur vision and distract from the main purpose of the games.

Game #1 Cat vs Mouse

The idea of the game is to control the mouse's direction and speed by tilting the tablet PC and to collect as many cheese chunks as possible in one minutes time (See Fig. 1). The player gets 10 points for each cheese chunk collected. The game ends when the time is up or when the opponent (a cat) catches the mouse.

The game starts with no opponents. The bar in the middle of the screen is an impenetrable obstacle that has to be bypassed. The first opponent, a cat, joins the game after the mouse has collected 50 points (5 chunks of cheese). From that point on the cat keeps on chasing the mouse, which puts a little more difficulty into the game. The next cat joins the game after the player has collected 100 points. At the same time the first cat gets faster and harder to evade. The last opponent joins the game after 150 points while the two existing opponents again get somewhat faster.

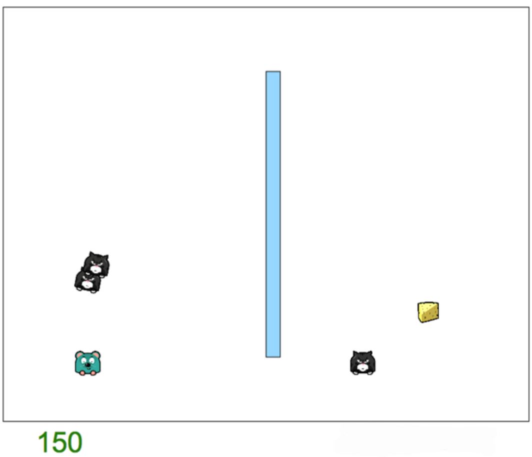

Fig. 1. Game#1 screen. The blue mouse is controlled by titling the tablet PC. The idea is to collect cheese and avoid the cats.

To play the Cat vs. Mouse required no push-button actions. The game was controlled simply by tilting the device (tablet PC or cell phone). The game elements (mouse, chunk of cheese and cat) were selected to facilitate the perception of the simple game logic. The fact that mice love cheese, and that cats love chasing mice has not changed over the years and so makes the game logic easy to grasp even for people who are 90+ years of age.

Game #2 Modified Trail Making Test

The second game is an interactive, slightly modified version of the traditional Trail Making Test . In addition to providing cognitive stimulation and recreation, the purpose of Game #2 was to collect data on the performance and progress of the test group of players and to link these to their particular gaming history (Game #1 and Game#2).

A traditional Trail Making Test contains part A and part B. Both parts consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the testee should draw lines to connect the numbers in ascending order, or in this interactive version, by tapping the numbers in ascending order. In Part B of the traditional test, the circles include both numbers (1 – 13) and letters (A – L). The testee draws lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (A-1, B-2, C-3 etc.). The testee is instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. The time taken by the testee to draw the "trail" is measured. Possible errors are pointed out immediately and the testee is allowed to correct these and continue the test. Errors affect the patient's score only in terms of the increased completion time of the task. In traditional use, it is unnecessary to continue the test if the testee has not completed both parts within five minutes. Results for both Trail Making Test -A and B are reported as seconds required to complete the task; the higher score (i.e. time required) the greater the impairment [12, 14-17].

Only Trail Making Test -A test was used in our game trials due to the high average age and rather high memory impairment of the testees. In Game #2, the circled digits are randomly spread over the tablet screen and the testee is instructed to tap the circles in the right order as quickly as possible (See Fig. 2). When the correct digit is tapped it turns more transparent. If the testee makes an error, the incorrect digit circle tapped on turns red (original digits are drawn in blue). To better accommodate the older users, the digits were made relatively large and coloured visibly. The indication of incorrect tap was also made to be as noticeable as possible. The game ends when all circles are tapped in the correct order or after four errors. The difficulty level can be raised in the game menu by increasing the amount of digits on screen. In this study trial, the difficulty level was supposed to be raised each week by adding five more digits on the screen.

Fig. 2. Game#2, A modified electronic version of Trail Making Test -*A.*

In transferring this test to a tablet PC based application, the designers also omitted the line drawing component of the original test. Instead of combining the digits by drawing a continuous line, players were required simply to tap the digits in sequence. This change or simplification might have affected the results. However, the idea of the interactive game is still quite similar to the original test, in which the person is required to find and also connect the numbers in the right order, which is closely related in terms of the cognitive skills used as well. [34,35]

Conducting the study

Before the actual game trials, the games were tested by the rehabilitation staff. A special attention was paid to usability issues in the games. Since the game development was seen as an iterative process, further improvements were realised according to phase-by-phase user feedback. During the study, the games were played in a semi-controlled environment in which care staff was present assisting on request and observing the players.

The target group comprised of older adults (≥80) with mild or medium memory impairment based on memory tests (CDR -rate 1-2, MMSE -points 12-26/30; tested by specialist memory nurse) and who were living in assisted living environments [18, 19]. Participation was on voluntary basis confirmed by a signed consent. Participants were well informed about all details in the research setting, including written instructions on how to use the tablet PCs and how to play the games. Prior to study recruitment, university ethical committee approval was obtained.

Participants (N=16) were all male with average age of 90 years (Table 1). All the participants were residents in War Veteran's Nursing Home and Rehab Centre run by West-Finland's Diaconese Institution. The sample was intentionally kept rather small since this study was supposed to be a preliminary trial with the selected target group. Participants were volunteers willing to join the trial, and the total group was divided into two identical groups (control group and test group) by the medical staff of the Institution based on the volunteers' previous memory testings and general health condition.

All participants were diagnosed with mild or medium level memory impairment. One of the test group participants was bedridden (n=1) and one had severe cardiovascular condition (n=1). Otherwise the participants were in good age-related health condition. After the first few weeks, the participant with severe cardiovascular conditions had to be replaced with one of the control group participants. This swap caused the imbalance in final number of groups presented in table 1.

Table 1. The scope of age and MMSE scores of participants.

Test Group			Control Group		
ID	**age**	**MMSE**	**ID**	**age**	**MMSE**
ID1	90	23			
ID2	91	23	-	92	25
ID3	91	22	-	87	21
ID4	91	21	-	89	23
ID5	90	22	-	80	26
ID6	88	26	-	89	16
ID7	90	14	-	97	23
ID8	90	24	-	97	12
ID9	91	25			
Mean	**90.2**	**22.2**	**Mean**	**90.1**	**20.9**

Playing the two games installed on the mobile devices required internet connection and player registration to the server database. Player identification utilised NFC-technology, and required a separate player-specific ID-tag delivered to each player. The tablet PCs used in this trial employed the Android operating system enabling deployment of Near Field Communication (NFC). NFC is a set of standards for smartphones and similar mobile devices to establish radio communication with each other by touching them together or bringing them to within a few inches proximity. Present applications include contactless transactions, data exchange, and simplified setup of more complex communications such as Wi-Fi. Communication is also possible between an NFC device and an unpowered NFC chip, called a "tag". Programmable tags, embedded in pieces of paper or plastic communicate with devices via the short-range radio technology (NFC) [42.] In this trial, each player started their game period by touching the Android tablet with their personal identification tag. After reading the ID-tag, the tablet asked the player to confirm their identity read from the tag and then displayed on the screen simply by pressing a yes or no button.

Each participant was tested by the target organisation's specialised memory nurse using standardised Trail Making Tests prior and post the 3-month gaming period. The members of the test group played mobile games on a daily basis according to the schedule provided, for three months (the objective being a total of 91 game days). The games played were alternated between cheese chasing and trail making in turns, every second week (cheese-chasing every even, trail making every odd week). The outcome was measured as the change in the course of gaming, not as the absolute amount of points gained (Table 2).

Table 2. Game schedule for the intervention group

Week	Game	Note
1	Cat vs Mouse	daily 2 x 5 minutes
2	Trail Making Test / with 10 digits	daily 2 x 5 minutes
3	Cat vs Mouse	daily 2 x 5 minutes
4	Trail Making Test / with 15 digits	daily 2 x 5 minutes
5	Cat vs Mouse	daily 2 x 5 minutes
6	Trail Making Test / with 20 digits	daily 2 x 5 minutes
7	Cat vs Mouse	daily 2 x 5 minutes
8	Trail Making Test / with 25 digits	daily 2 x 5 minutes
9	Cat vs Mouse	daily 2 x 5 minutes
10	Trail Making Test / with 30 digits	daily 2 x 5 minutes
11	Cat vs Mouse	daily 2 x 5 minutes
12	Trail Making Test / with 40 digits	daily 2 x 5 minutes
13	Cat vs Mouse	daily 2 x 5 minutes

The control group was tested similarly to the test group by the specialised memory nurse prior and post the 3-month trial. The control group was not involved in the game trials but was only used as a comparative cohort to assess the possible effects of gaming on reaction and memory abilities.

The duration of the game trial was scheduled for three months to obtain an adequate amount of data in order to detect possible tendencies in gaming processes and score developments. This relatively long gaming period also provided time for each participant to become familiarised with both the tablet PC device and the games [37]. In addition, the three month period was reckoned adequate to test participants' motivation after possible charm of novelty had worn off. Effective rehabilitation is typically a long-term process requiring commitment and persistence in order to attain and maintain desired abilities [28,36,43].

This study focused on finding out possible measurable impacts and user experiences of gaming of older men:

- Possible impacts of the 3-month trial period with selected mobile games to the selected target group's Trail Making test results.
- The quality of experiences of older men on mobile gaming as part of self-managed activation and cognitive rehabilitation

The older adults' self-assessment of gaming period's impacts on their attention and memory abilities required in daily activities.
The quality of experiences of older men on usability of a tablet PC and the two installed mobile games.
The user experiences and usability was seen as defined by ISO 9241-210 [45] as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service". According to the ISO definition, user experience includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after use. The ISO also list three factors that influence user experience: system, user and the context of use. User experience issues were collected from the test group by means of a semi-structured interview after the 3-month gaming period. Each participant was interviewed privately in order to obtain as much authentic and subjective information as possible. The interviews consisted of structured questions related to participants' previous experiences on and use of mobile games and devices, subjective experiences about the trial period and its impacts on participant's cognitive skills and general well-being, subjective experience of participating in the trial, and participants' comments on the usability of the devices and games in general. In addition, care staffs' observation notes and comments were collected and analysed to ascertain reflections base on participants' subjective experiences.

The data was analysed thematically based on the research questions by calculating quantities in frequencies and percentages, and the qualitative data categorised by contents analysis.

3. Results and Discussion

A) The effects on cognitive skills

Game#1 Cat vs Mouse

The game scores of Game #1 show a great variety in the results between the players (Figure 3 and Table 3). Almost all of the players improved their scores; only in two cases (ID 3 and ID 9 in Table 3) the game score decreased. It is worth mentioning that one of the testees had to cancel his participation due to a sudden collapse in his health condition (ID 2, last score in database 26th June). Another testee was selected from the control group to replace him in the test group (ID 3). This might partially explain the decreasing result of ID3, since he only played the game 30 times and for a shorter period of time (from 4th July to 8th August). Also ID 7 discontinued the trial for six weeks (from 15th June to 27th July) after which he re-entered the trial. ID 9 played only 17 games (between 29th of May and 1st of June) which is significantly less than most of the other players did. ID 9 also focused only on playing the Game #2 (See Table 4).

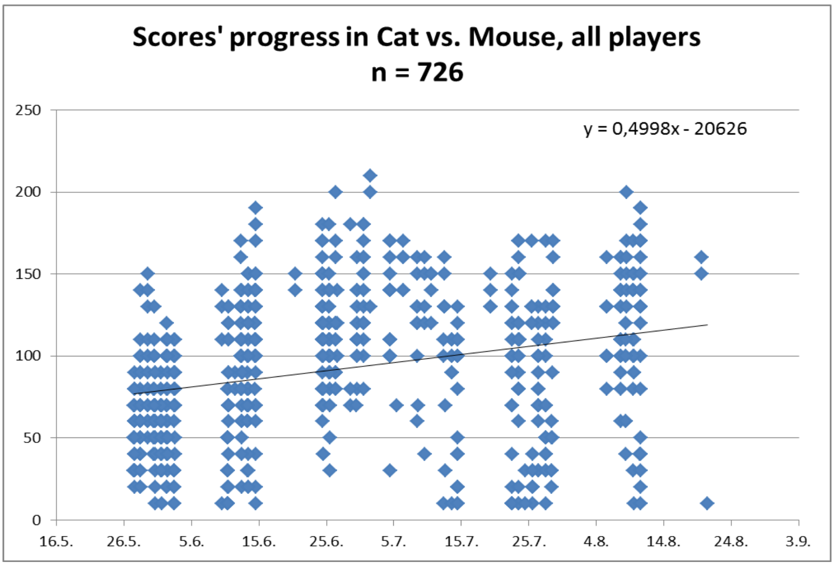

Fig. 3 Game scores of all the players in Game #1. Total number of games n=726. The X-axis shows the game date and the Y-axis shows the game score. Each dot represents one game score.

ID 5 was the most active player and also obtained the highest scores in general. ID 5 improved his scores by about 35% whereas ID 7 with the lowest scores in the beginning and significantly less number of games played, improved his scores almost 74%. In addition, ID 8 with a low score in the beginning only improved his scores about 19%. This implies the highly individualistic nature of the progress among the testees. The results of individual players also indicate large variance in game scores between separate shots even within the same day (Fig. 4). A trial with a much larger test group is necessary in order to find any correlations between the amount of games played, the game scores achieved, and the improvement attained in game scores. However, it could be concluded (Table 3) that players with higher scores were in general more active in game play than those with lower scores.

Table 3. Changes in the game scores of individual players (Game #1).

ID	Slope of regression line	Change (%)	Regression line value at the beginning	Regression line value at the end	Number of games
1	0.268	29.63 %	67.828	87.928	70
2	1.0557	62.39 %	54.15	87.93	79
3	-1.3222	-113.16 %	43.23	5.69	23
4	0.5521	59.70 %	79.53	127.01	94
5	0.454	34.82 %	112.13	151.18	280
6	0.5136	68.14 %	64.83	109.00	84
7	0.2427	73.58 %	23.09	40.08	48
8	0.0673	18.73 %	26.23	31.15	30
9	-0.9044	-4.24 %	64.04	61.33	17

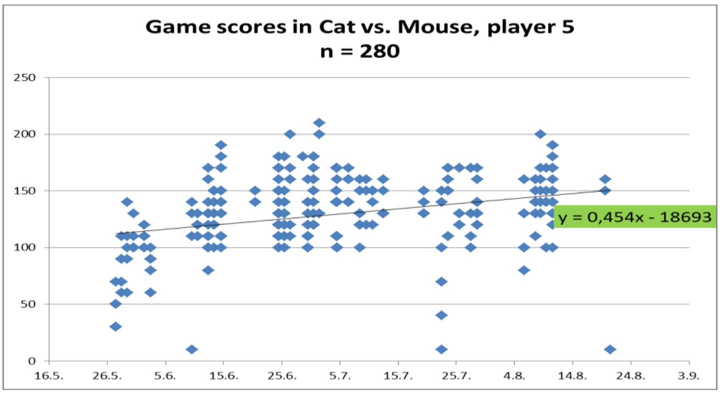

Fig. 4. Typical result profiles of Game#1 present a large variation in game scores.

The most significant finding is that despite the testees' advanced age, improvement in results related to attention and reaction skills was achieved during the three-month period. Also the intensity of gaming remained stable during the entire three-month period indicating participants' high motivation and interest. In conclusion, based both on the participants' and staff oral reports during the interviews, even for people over 90 years of age, familiarising oneself with how to use the tablet PC and play the games was easy. All the participants got the instructions in writing and pictures in advance, and one staff demonstrated the use for each participant before the first play. To simplify the use, no additional programmes apart from games were installed in the trial tablets. Participants themselves were happily surprised how easy and quick it was to learn the procedure. In the future, similar game trials should be arranged with a younger target group with a better overall health condition and a larger number of testees.

Game #2 modified Trail Making Test

The scores of Game #2 (modified interactive version of the Trail Making Test) are introduced in Table 4 and Figs. 5-7. The total number of games played was 696 and included all difficulty levels. Table 4 illustrates the progress of each player at different levels. The slope of the regression line presents the change indicating the progress in general in the capability level of each player over the course of the trial (Table 4). The games discontinued after four consecutive errors. The error frequencies are presented in the tables in percentages. Table 4 also presents the number of games played at each level. Only difficulty levels >25 are excluded from the table due to a very small amount of games played at this level.

Table 4. Players progress indicators at different difficulty levels.

Player	Slope	Regression line value at the beginning	Regression line value at the end	Games played in level 10	Errors in level 10	Error percentage in level 10
ID1	-13.066	141	75	13	0	0.0
ID2	-3.9967	50	26	38	0	0.0
ID3	-1.8207	63	35	9	0	0.0
ID4	-1.5724	26	18	22	11	50.0
ID5	-2.7652	56	40	36	7	19.4
ID6	1.5151	33	40	17	0	0.0
ID7	-0.9885	131	86	13	0	0.0
ID8	-0.1269	63	55	42	4	9.5
ID9	-0.6269	26	10	73	6	8.2
Player	**Slope**	**Regression line value at the beginning**	**Regression line value at the end**	**Games played in level 15**	**Errors in level 15**	**Error percentage in level 15**
ID1				3	0	0.0
ID2	-1.228	43	40	32	0	0.0
ID3				4	0	0.0
ID4	-0.0436	39	37	22	3	13.6
ID5	-3.601	56	46	23	0	0.0
ID6	-0.2189	49	42	14	0	0.0
ID7				1	0	0.0
ID8	0.3493	85	106	24	2	8.3
ID9	-0.2045	45	37	44	1	2.3
Player	**Slope**	**Regression line value at the beginning**	**Regression line value at the end**	**Games played in level 20**	**Errors in level 20**	**Error percentage in level 20**
ID1				3	1	33.3
ID2						
ID3				2	0	0.0
ID4	-0.5375	54	38	21	9	42.9
ID5	-3.0438	97	82	43	11	25.6
ID6	-0.8542	76	50	14	0	0.0
ID7				2	2	100.0
ID8	-1.1553	197	126	14	3	21.4
ID9	-0.9143	86	58	40	2	5.0
Player	**Slope**	**Regression line value at the beginning**	**Regression line value at the end**	**Games played in level 25**	**Errors in level 25**	**Error percentage in level 25**
ID1				4	3	75.0
ID2						
ID3						

ID4				3	1	33.3
ID5	1.9376	96	127	24	5	20.8
ID6				2	0	0.0
ID7				10	9	90.0
ID8						
ID9	0.3086	83	89	19	0	0.0

Most of the players improved their Trail Making Test game scores (indicated by a negative slope, i.e. a shorter time to finish the test) at levels 10 to 20 but after increasing the difficulty level up to 25 digits and more the game times decreased and the progress in the results ceased. The players explained that too many digits displayed on a 7-inch screen complicated the game excessively, which removed the motivation to play on. Also the staff reported that 25 digits was the obvious top limit after which the players became irritated and stopped playing. Another finding was that achieving the optimum progress in the games required regular playing which we did not see at the higher difficulty levels. The data revealed that Game#2 was not actually played according to the instructions given regarding increasing the difficulty level of Game#2 at each test week. Instead, some of the players continued playing at lower difficulty levels till the end of the trial period.

Interestingly, the standardised pen and paper type Trail Making Test -A test consists of 25 digits to be connected by a line. In this interactive game version of Trail Making Test , level 25 was considered as already “too difficult”, most likely because on the 7-inch screen with large digit circles it became a tight squeeze for tapping. Whether an increased or prolonged playing period would develop the older old player’s dexterity sufficiently to overcome this challenge would be worth considering and investigating in future studies.

Another significant finding indicates a great variance in the individual player’s test scores (See Fig. 5). The game scores are dependent among other things on the older players’ general health condition which may vary from day to day. In addition, there is also a relatively large variance in the game scores even on the same weekday. A typical result profile of a testee is shown in Fig. 5.

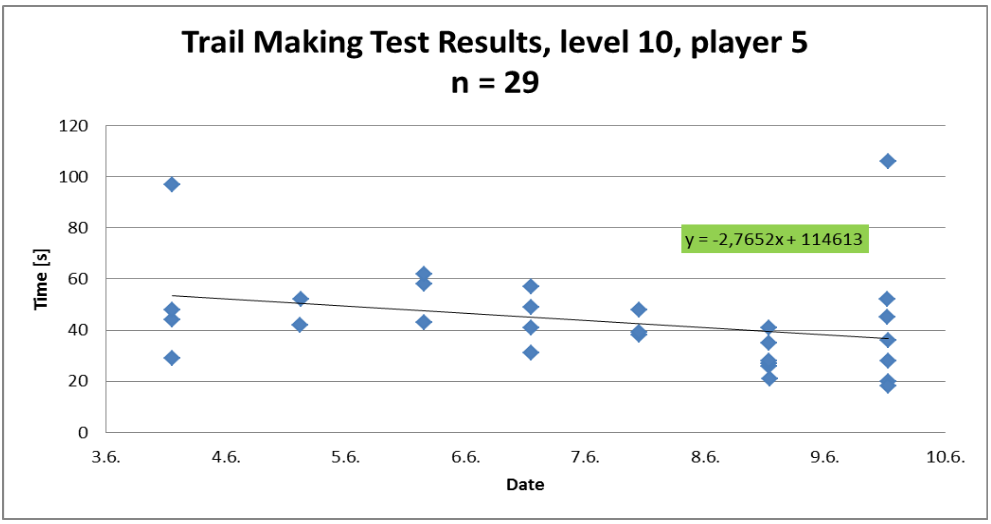

Fig. 5. Typical result profiles of Game#2 shows a large variation in game scores

The observation of rapid changes even on the same day in participants' perceptiveness raises the question of whether this fact should be better taken into account also in the standardised Trail Making Test . Typically the standard Trail Making Test is performed only once at any given time. Based on our findings, the risk in pen-and-paper tests is that the person may accidentally have either a "high score" or "low score" moment when tested. And therefore the results might not be the whole truth of their overall condition, which would more likely become verified with sequenced testing. However, the key feature distinguishing our interactive game version from the standardised pen-and-paper Trail Making Test was the omission of the requirement for drawing the line to connect the digits in correct order. The drawn line seems to be the "trick" in the standardised Trail Making Test , which is also is confirmed e.g. by Poreh et al. [34] and Ashendorf et al. [44]

The regression line slope at different difficulty levels is illustrated in Fig. 6 and the games which ended due to four errors are presented in Fig. 7, to give an overall view of the game progress. Fig.6 shows that most of the players have negative slopes indicating the improved trend in results. Each player gained improved scores at least in some levels of the game. It is also seen that the slope varies in each level and eventually no positive progress is seen at level 25. No further indication of the correlation between difficulty level and slope is found within this small test group or within the even smaller group of players who actually attempted the higher difficulty levels. Players 1, 3 and 7 are excluded from Fig. 6 because the players only played in one game level (level 10).

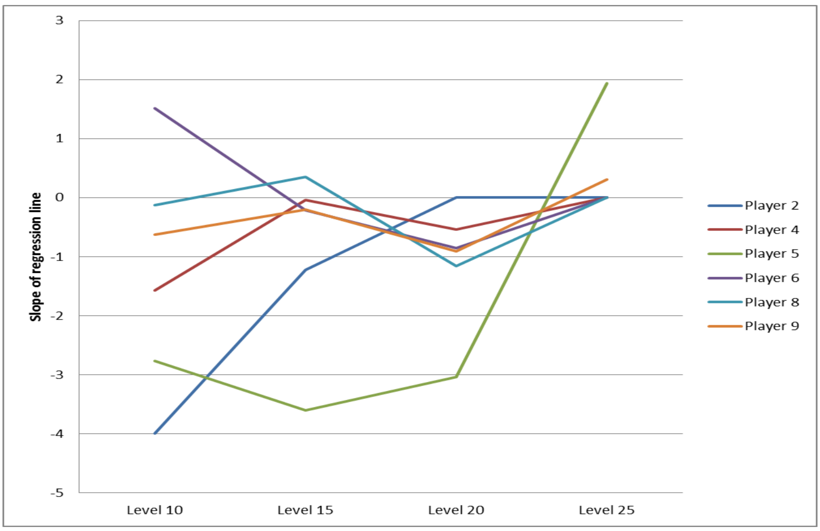

Fig. 6. The slope of regression line at different levels of difficulty in Game#2.

Error frequencies are presented in Fig. 7. The number of games which discontinued after four errors increased according to the increased difficulty level. The statistics are very likely skewed due to the evidence that more skilled and motivated players were more likely to try the higher difficulty levels where as weaker players tended to skip them .

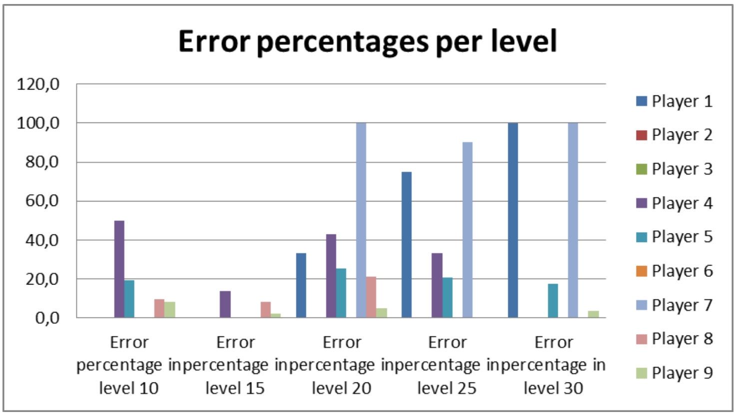

Fig. 7. Games that eneded due to 4 errors, each player shown separately.

In general, small improvements in game scores were found. However, a more important finding is that the game scores of each individual player varied significantly even on the same difficulty level. Playing the higher levels of Game #2 was avoided. Based on the participants' comments in the interview, the excessive challenge experienced removed their motivation to play the game at this level of difficulty. This phenomenon is well known and explained by flow theory which provides a coherent and universal model for the degree of engagement: the game challenge and what the player's skills should be in order to facilitate the sense of flow. In Game#1 the difficulty increase was dependent on the progress of each player, which is why this game was well accepted and played regularly over and even beyond the entire trial period. It could be concluded that this kind of special groups are no exception when taking the game design and flow theory into consideration. [20]

B) Qualitative findings of the trial

Participants' subjective experiences and comments regarding the trial were collected by semi-structured interviews. Each participant was interviewed separately to obtain optimum authentic data. The care staff members who had been involved in the trial were also interviewed, and the email communication between the project director and the trial field coordinator was included in the research data.

The overall feedback from the trial period was extremely positive. The games concerned were seen as interesting, exciting, entertaining and they obviously caught the participants' and their family members' interest. Even if the memory test results did not show significant improvement over the trial (See Table 5), all of the participants reported their activation level, attention skills and overall well-being improved. The games provided participants with something interesting to do during the daytime. In addition, the participants reported that gaming was something they could do any time feeling so unlike many other activities that were bound to staff working hours. Enabling the residents' indipendent activity by offering free access to mobile games individually or in groups is shown in this trial, even with a small sample, worth investing in. The more mindful activities the residents have free access, the more the staff is released for other care activities. Game play also increased the level of social interaction between the participants, their family members and the staff. The positive feedback resulted in the purchase of several tablet PCs with games for residents.

In general, tablet PCs have quite a number of useful functionalities and applications available for individualised purposes. However, extending the pallet of software available would require deeper instruction on how to use the tablet in general. Further studies related to cost effectiveness and benefit of the games and tablet devices compared to other activities offer an interesting future research topic. Another interesting topic would be to study whether any other activity would create similar experience of improved well-being as reported being the results of this gaming trial in terms of social interaction, contents, motivation, improved dexterity etc.

The meanings set for and taken from the game play varied widely. In addition to being an interesting thing to do, the games also provided participants with a sense of obtaining new skills. The dexterity in movements required and mastered meant that participants experienced a decrease in joint stiffness and the thinking required for game play meant a lessening of the sense of a mental void. Additionally, the shared sense of increased liveliness opened new possibilities for more rewarding social interaction with family members, other residents and even with the staff. Only one participant commented that playing such games was not "his cup of tea", and saw it as a childish and meaningless activity.

Staff saw the game play as generally being activating and entertaining but most importantly as being quite rehabilitative. Based on the staff observations, the participants visibly improved their dexterity and their general motor skills needed to handle the devices which enabled them to obtain improved scores, too.

The tablet PCs were commented on as being easy-to-use and light to handle. The only issue worth mentioning was the rather frequent comment regarding the problematic touch sensitivity of the tablet screens. Several participants commented that the touch screen did not react to their tapping, which naturally affected negatively on game results in terms of generating false errors and increasing game play time. The touch sensitivity has been made as easy to trigger as possible within the game application source code. In the tested version, a touch event was even triggered when the player lifted their finger from the screen. This is seen quite effective in comparison to for example a click-event, where player must put his/her finger down and up in the same position within a certain time in order to trigger the expected event. One possible reason for the poor touch sensitivity might be fingertip dryness which is why electricity is not conducted as effectively as with moist fingertips. This is one down side to the otherwise effective working of capacitive touch screens (where function is based on the change in capacitance caused by an electrically conductive object such as human touch). For future trials with older adults, a touch pen or touch gloves could be used to increase touch sensitivity. Another option is to employ resistive touch screens which do not require the touching object to be electrically conductive.

NFC-technology was used for automatic player logging in the game. NFC enabled fast identification simply by lightly touch with an ID-tag on the reader integrated into the mobile device. The tag was embedded within a card and stored player identification information to assist in log-in without the need for memorised codes. This technology was also well accepted by the participants. The technology has potential in various other situations where people may have problems in remembering the required usernames and passwords needed for log-in. NFC could also be used as a trigger and therefore decrease the amount of icons on the touch screen required to open applications or software on the mobile device.

In general the games received a warm welcome by the participants and staff involved in this trial. All except one were convinced that game play could benefit old people with positive impacts on their physical, mental and social well-being. The results in this study encourage further testing and game development targeted specifically at older adults challenged by cognitive impairment. Despite its limitations, this study provided parallel results to previous studies endorsing gaming as means for self-managed activity combining physical, cognitive and social elements to enhance older people's well-being.

Limitations

Elements defining normative reference values of Trail Making Test for various age groups are assessed and reported in several articles [e.g. 21,34,35]. Gender, age, education, IQ, sample size and exclusion criteria are the parameters that should be considered while dealing with these norms. In addition, the norms should include average result and standard deviation of the results [43]. According to the articles, gender does not affect the Trail Making Test results. In Trail Making Test A education is also irrelevant although the significance slightly increases by age. This is why in this study any further categorisations of the testees were not included.

According to Tombaugh [21], average score of people aged 85-89 are: 58sec (education < 12) and 63sec (education > 12). In the norms, all people having neurological disease, psychiatric illness, head injury, stroke etc. were excluded. All participants were living independently in the community. There were no norms for people at age of 90+ whereas the majority of the testees in our trial were at this age category (Table 1). In addition in our trial all of the testees had memory and cognitive impairment (only four of the sixteen testees scored ≥25 in MMSE, See Table 1) and all of them live in an assisted living or nursing home environment. This is why it is no surprise that the test results in general are lower than any of the norms. The average time used for the traditional Trail Making Test by all the participants (control group and test group) before the test period was 218 sec. and the standard deviation 191 sec.; and respectively after the test period: 226 sec and 123 sec.

The standardised Trail Making Test test results of this trial for test group (A) and control group (B) are shown in Table 5. Note that only those trail making tested participants who took part in the entire trial period are presented in the table 5. ID 1, 2, and 7 were not able to participate in the entire trial processes due to their decreased health condition. ID 2 was replaced by ID3 (originally in the control group) 5 weeks after the launch of the trial.

Table 5. The results from traditional Trail Making Test A before (Trail Making Test 1) and after (Trail Making Test 2) the three month test period.

Group	ID	Trail Making Test 1	Trail Making Test 2
A	ID3	114	326
A	ID4	84	127
A	ID5	250	150
A	ID6	137	176
A	ID8	600	381
A	ID9	135	484
B	-	96	98
B	-	359	234
B	-	69	78
B	-	67	99
B	-	619	315
B	-	133	234
B	-	177	241

The main limitation in this trial was a relatively small test group, with limited amount of data, which is why no far-reaching conclusions can be made regarding the effects of the two cognitive stimulation games employed in this trial compared to traditional Trail Making Test . In this trial, the participants were intentionally selected to be 80+ male being the main characteristic of the residents in the target Institution. In addition, the original purpose was to find out the applicability of mobile games in order to improve or maintain the attention and memory abilities of older adults required in daily activities.. Participants in our trial were ≥ 90 years of age on average, and therefore beyond the normative Trail Making Test reference values. The Trail Making Test results as mean and standard deviation for the test group are: 220s and 195s before test period, and 274s and 145s after the test period. The equivalent values for the control group are: 177s and 204s before the test period and 241s and 92s after the test period. Both test and control group results are far lower than reference values presented by Tombaugh [21]. However, this trial evidenced that 2/6 (~33.3 %) of participants in the test group and 2/7 (~28,6%) of the control group improved their Trail Making Test scores.

The results from the traditional Trail Making Test A (Table 5) are though parallel to the gaming results (Table 4) indicating too high difficulty level in Trail Making -game compared to player's skills. Further research is needed to evaluate, whether even the lower difficulty level test would work as a tool to measure mild or moderate memory impairment.

Although the group in this trial is not statistically large enough, some significant findings were achieved, like acceptance of games as a recreational activity by older people, great variance in individual game scores, and the fact that people are able to learn and improve despite of their memory impairment and relatively high age. The findings in this study are parallel to previous studies confirming that motivation and recreational value are significant elements in making games a valuable means in self-managed activity and rehabilitation of older adults. Similar game trials need to be arranged also for various target groups with a wider age range to obtain evidence on the impacts of gaming as means of self-managed activation and rehabilitation. This trial provided as well indications on necessary modifications in game intervention setups in order to eliminate similar limitations as present in this study.

4. Conclusions

In this study tools with the potential for self-rehabilitation, as cognitively stimulating mobile games, were developed and investigated. Both motivation and rehabilitation elements are required for a self-rehabilitation tool. This is why in this study both the acceptance and recreational values and effects of games were assessed in a three-month intervention setting.

Two different types of mobile games were developed particularly focusing on improvement of older people's attention and reaction skills. The target group was a group of men >80 years of age with mild or medium level memory impairments who lived in either an assisted living or a nursing home setting. The test group's user experience and usability assessments were collected by a structured interview after the 3-month gaming period. The game progress data was collected on a server utilising NFC technology. The cognitive skills assessment was performed by a professional memory nurse using standardised Mini Mental and Trail Making Tests. The test results indicate no significant improvement in cognitive skills after the three-month trial. However, most of the test group members improved personal game scores (Game #1) during the intervention period. The modified interactive version of Trail Making Test (Game #2) results were also improved in lower difficulty levels (≤25). The progress data of the interactive Trail Making game presented high variance of individual player's test scores indicating that a single test should never determine the person's condition.

Participants' Trail Making game scores varied significantly from one game instance to another, which makes it difficult to draw any sharp conclusions about the effects of the games in terms of cognitive skills. The game scores (Game #1 and Game #2) did vary from day to day as well as from one instance to another even on the same day. It would be worth investigating whether the situation was the same in the standardised pen-and-paper Trail Making Tests . In this study, the change between pre- and post-trial measures of standardised Trail Making Tests in the control group is more than 50 seconds in 4/7 cases, and 3/6 in the test group. A longer test period and larger test group are needed to further investigate the effect of the games on traditional Trail Making Test A results.

In general, the game interventions were well accepted by the participants, professional staff as well as the participants' family members. Surprisingly significant was the effect of the games in respect of observed activity, recreation, and improvement of general well-being. Based on the participants' oral reports in the interviews and the staff observations, the mental attentiveness and well-being of participants improved during the 3-month gaming period which also indicates that the gaming activities had positive influence and meaning in participants' experienced well-being and state of overall health.

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III

INTELLIGENT MACHINE VISION SYSTEM FOR MEASURING GEOMETRICAL CHARACTERISTICS OF REINFORCING BAR

by

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Intelligent Machine Vision System for Measuring Geometrical Characteristics of Reinforcing bar

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Keywords: machine vision, 3D imaging, geometrical characteristics of reinforcing bar, silhouette

Abstract. Reinforcing bars (re-bars) used in concrete building are strictly standardized. For the re-bar to fulfill the requirements set by the standard manufacturers have to measure samples taken from cold-rolled re-bar. The most commonly used method in measuring the re-bar is taking the sample from the rolled re-bar and measuring it with calipers. If the measurement is done with calipers, the resolution, repeatability and speed won't reach desired level of accuracy/precision. For the measurement process to be sped up and make it more precise, it needs to be automated. From the re-bar quality control's point of view, the significant geometrical characteristics are; rib height, rib angle, distance between ribs, rib's longitudinal cross-sectional area, rib flank inclination and distance between rib rows. The goal of the machine vision based measurement system that is presented in this article is to measure these geometrical characteristics from B500K-reinforcing bar.

Tests made in Satakunta University of Applied Sciences RDI-laboratory showed that imaging based on silhouette would be the best way to achieve measurements that would achieve requirements set by the standard. Measuring system's resolution goal was set to 0.05 mm. The camera and optics that were chosen for the system would give theoretical resolution of 0.03 mm, which fulfills the resolution goal.

Re-bar measuring system based on machine vision was planned to be done with a 10 Mpix machine vision camera, telecentric optics, backlight, stepping motor which rotates the re-bar rod and a stand which combines all these. Images taken by the camera are transmitted to the computer to be analyzed. Machine vision program processes the images and creates an accurate 3D-model as a result from which every geometrical characteristic can be measured. Measurement system is in testing phase at the moment, and its accuracy is being tested by comparing results gotten from the measurement system to measuring results from a certified measurer.

Introduction

Machine vision has become more common as part of automatic processes during the past decade. Machine vision cameras' accuracies are in a level where complete systems can be built around average priced cameras, in which different features can be analyzed more accurately than with human eye. In the same time, the diversity of analysis software and out of the box tools of the software allows easy application development. Because of these reasons the measurements of re-bar geometrical characteristics presented in this article, were able to be done based on machine vision.

The re-bars used in concrete building are strictly standardized. Certified third party makes sure that the standards are followed, by inspecting samples taken from production lines time to time. Finnish Standard Association's SFS standard SFS-EN ISO 15630-1 states the experimental methods that should be used in measuring concrete steel rods, -hanks and -threads. In order to fulfill the requirements set by the standard, the re-bar manufacturers are also measuring re-bars taken from the production. [1]

In re-bar manufacturing generally used measuring method is to measure a sample from production with a caliper. If the measurement is done with caliper, the resolution, repeatability and speed won't reach the desired level. For the measurement process to be sped up and to make it more precise, it needs to be automated.

The re-bar manufacturing company gave a challenge to Satakunta University of Applied Sciences (SAMK); would it be possible to automate the re-bar geometrical characteristics measurements. Application development occurred in SAMK's RDI-laboratory by a four person machine vision team. System planning, execution and testing of different versions have been going on for over 18 months and it has taken almost 9 person-workmonths to get here. One of the main research areas of SAMK in 2010-2013 has been machine vision and learning machines. [2, 3]

Challenges in measuring geometrical characteristics of re-bar

The quality control of the re-bar cold-rolling manufacturing process is mostly sample-based quality control. Samples are taken from production on steady intervals and they are measured with calipers in the measuring laboratory. The most important geometrical characteristic to be measured in cold-rolled re-bar is the height of the rib, because the height changes as the roll wears down. Other measured geometrical characteristics are: rib angle (the transverse rib angle to the longitudinal bar), distance between ribs, rib's longitudinal cross-sectional area, rib flank inclination and distance between rib rows (Fig. 1). From these, rib height, distance between ribs and the distance between rib rows can be measured with calipers, but the rib's longitudinal cross-sectional area, rib angle and rib flank inclination measurements require different type of measurement methods.

The goal of the measuring system based on machine vision that is presented in this article, is to measure certain dimensions from B500K-re-bars:

- rib height

- rib angle
- distance between ribs
- rib's longitudinal cross-sectional area
- rib flank inclination
- distance between rib rows

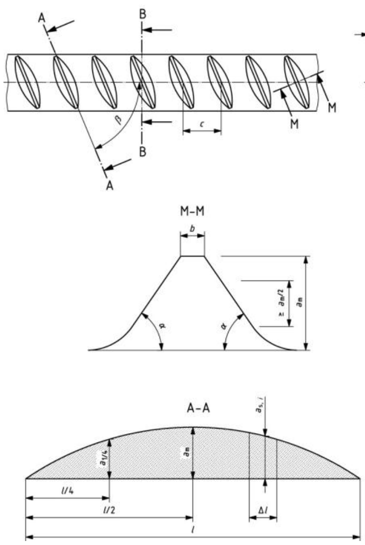

Fig. 1 Determination of the rib flank inclination (*α*) and determination of the area of the longitudinal section of the rib [1]

Measuring system's accuracy goal was set to 0.05 millimeters. This is the theoretical resolution of calipers, but in practice, measuring something with calipers visually accurately and repeatedly on the same value is very challenging, which causes the measurement to suffer significantly. [1]

Methods

When planning the re-bar measurement automation, options were either integrating the system straight to the production line or to make a movable measurement system which would be used in the measurement laboratory. In this first phase of automation it was chosen to create a system which would be located in the measurement laboratory. When deciding upon the measuring methods, machine vision proved out to be the most useful because of its speed, accuracy and versatility.

Machine vision system planning was started out with testing different imaging and lighting methods. Methods that were tested consisted of: creating a laser line on surface, and measuring the height from the difference of the laser line, stereo imaging system and imaging against a backlight, creating a silhouette image from the object that was being imaged. When testing these methods, it was shown that laser line turned out to be impossible to make accurate, because it reflected too much from a shiny metal object, and thus not meeting the resolution requirements. On stereo imaging, the biggest problem was the limitations of the technique. Measuring the re-bars' shapes very accurately could not be done with stereo imaging technique, because absolute location information was required for even the smallest changes of the object. Silhouette based imaging was the only option, because it produced accurate enough results. [4, 5]

Silhouette imaging means that the object is imaged against a backlight, thus the object is shown as very dark in the image. At the same time the background is white, and this way, the edges of the object are shown very precisely (Fig. 2).

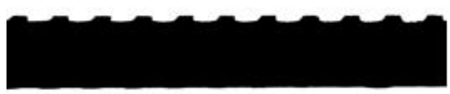

Fig. 2 Silhouette image of a re-bar

Silhouette based imaging technique's clear limitation is the two-dimensionality of the images. Taking a silhouette image of a cylinder object, will only gain a small portion of the cylinder's topography. To gain the topography of the whole cylinder would require images from infinite number of different angles. In practice, imaging from infinite number of angles is impossible, so a certain number of imaging angles would be set to achieve the desired resolution. After calculations, results showed that the re-bar should be imaged with approximately 1 degree intervals to create accurate enough results. To create a realistic image of the re-bar, it should be imaged in the same angle that the rib angles are. This way the silhouette consists of the actual profile of the re-bar, and the ribs won't distort the silhouette. This also limits the imaging so that the object can only be analyzed from the one side of the re-bar on the silhouette image. Based on these reasons, a stepper motor that takes 0.9 degree steps was chosen for rotating the re-bar rod.

Because the re-bar should be in a certain angle in relation to the camera to get a realistic silhouette image, the re-bar is at different distance from the camera from different points (Fig. 3). This causes problems with normal machine vision optics, because the area that is furthest away, looks like it is smaller than the same sized area that is closer to the optics. The problem can be fixed by inside the program, but a better solution is to use telecentric optics. Telecentric optics gathers light beams parallel from the area being imaged. This way, objects that are similar look the same size in the image, even if they are located at different distances from the optics. In practice, telecentric optic's depth of field sets limitations to the distance from which the objects can be imaged without losing the focus of the image. When using telecentric optics, the image area is smaller than the diameter of the lens. For this measuring system, a telecentric optics that shows 5 cm wide area was chosen.

Fig. 3 Placement of the camera, optics and re-bar in the measuring system

The 0.05 mm resolution goal of the measuring system set a requirement of minimum of 2000 pixels for image with diameter of 5 cm. Because of this reason, the camera that was used in the system was a 10 megapixel camera with the resolution of 3840 x 2748 pixels. The chosen camera has a ½ inch sensor, which gives a 56 x 42 mm area of image with the chosen telecentric optics. With these specifications, a pixel size is approximately 0.015 mm. This means that the theoretical resolution of the system is 0.03 mm, which fulfills the requirements. [6]

Solutions

For measuring the geometrical characteristics of the re-bar, a machine vision based system was designed. The system consisted of a 10 megapixel machine vision camera, telecentric optics attached to the camera, background lighting, a stepper motor for rotating the re-bar and a stand which assembles the whole system (Fig. 4). The images that the system takes are brought to the computer to be analyzed.

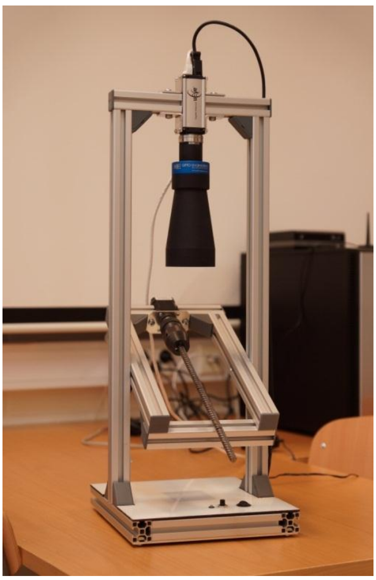

Fig. 4 Machine vision system for measuring geometrical characteristics of reinforcing bar

Images taken with the system are analyzed with a machine vision program. First the images are transformed into binary images by using thresholding. This way the re-bar is shown black and the background is white. All of the images taken from different angles are stored this way. Because the images aren't analyzed yet, the image acquisition is as fast as possible. After image acquisition, the re-bar can be taken off the system and the computer starts the image analysis.

From the stored images, the re-bar's movement is analyzed as it rotates around. With the help of this information the re-bar's rotation axel can be determined. When the axel is known, the silhouette analysis can begin. Silhouette edge is compared to the rotation axel, and that is compared to the silhouette image from the other side when the re-bar has turned 180 degrees. When this comparison has been done to all of the images, it can be deduced when the re-bar's ribs are vertical from the camera's point of view. Like this, an edge used in a silhouette image can be recognized. From these recognized edge points a point cloud is calculated trigonometrically. The point cloud is covered with polygons creating an accurate 3D-model of the imaged re-bar (Fig. 5).

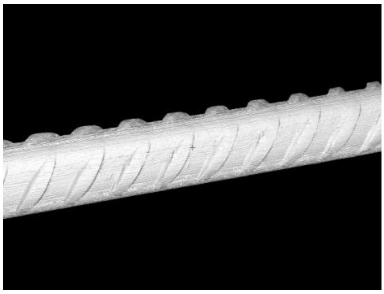

Fig. 5 3D-model created from a silhouette images of a re-bar

Distance between ribs, rib height and rib flank inclination is calculated from the 3D-model by first recognizing a plane parallel to the rod at the middle of the ribs. The 3D model cut by the plane is analyzed to recognize the rib models. From the recognized ribs the rib height and the distance between ribs can be calculated. The calculation of rib flank inclination works by creating a plane from the rib's center point to a 90 degree angle according to the rib. The 3D-model cut by the plane is used to recognize rib's rise, and from that, the rib's angle can be calculated. Ridge's longitudinal cross-sectional area is calculated by taking a cutaway parallel to the rib and comparing it to cutaways on both sides of the rib. Calculating the distances between rib rows, the information of longitudinal cross-sectional area is used

The created 3D model can be inspected on the computer screen, and it can be saved for later inspection, with the measurement information. With this feature, measurer can use information of earlier measured re-bars to gain information of the cold-rolling machinery's wearing and it's affects to the final product.

The machine vision system for measuring re-bar's geometrical characteristics is a result from long term applied research. This pilot system is the fourth version of the system during its trajectory. First phase of the development of the system was designing and testing the imaging and lighting methods. Perfecting these two methods took three different versions of the system. After the so called hardware side was completed, a more precise plan for the software and the execution of the plan was done. As a result, this pilot system was born. At the moment, the system is in testing phase, and its accuracy is being tested by comparing results with re-bars measured by a certified measurer.

Conclusion

The re-bars used in concrete building are strictly standardized. Certified third party makes sure that the standards are followed. In re-bar manufacturing generally used measuring method is to measure a sample from production with a caliper. For the measurement process to be sped up and to make it more precise, it needed to be automated. That is why a machine vision system for measuring re-bars' geometrical characteristics was designed so that its accuracy meets the measurement requirements set by the standard. The goal was to automate measuring process so that it would be faster, more accurate and repeatable. This goal was achieved, as the measurer is only needed when the re-bar is set into the machine and taken off. The re-bar attachment into the machine and the software is done so that the measurement can be repeated. Measurement results and the 3D model of every measured re-bar can be automatically saved.

A wide series of measurement tests is being carried out with the system, from which the real accuracy of the system will be known. In the future, the goal is to create a version of the system so that it can be integrated on the production line. This would make it possible to take real time measurements of re-bars, so that samples are no longer required.

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IV

OPEN INNOVATION BETWEEN HIGHER EDUCATION AND INDUSTRY

by

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Open Innovation Between Higher Education and Industry

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Abstract

A largely recognized fact is that knowledge creates the base for innovations in technology development. This means that enterprises need to adopt the newest technology knowledge in order to develop and create new innovations. This research is based on assumption that technology knowledge transfer should be executed according to the plan based on need recognition in order to enable open innovation processes between higher education institutions and industry.

In this paper the two types of open innovation processes are modelled. The models are described and evaluated with case examples. The models are based on the research and innovation projects carried out with university and enterprise partners during the last seven years. The projects have varied from technology evaluating projects executed mainly by the students to targeted open innovation projects conducted by the researchers. In the paper, e.g., the processes and models are illustrated with case examples.

The paper models technology transfer processes that have been created combined with targeted innovation processes and have been executed in practice. Comparisons between cases will be done, best practices will be pointed and filtering of explicit knowledge based on our tacit knowledge will be explained. Writers assume that partnerships based on trust will be one significant method to identify drivers towards targeted open innovation.

As the main outcome of this research two models of open innovation processes between a university and industry are modelled and evaluated. They are also connected to open innovation, technology transfer, Mode 3 knowledge production and Quadruple Helix innovation theories when they give one practical model of how to combine different modes of innovation in knowledge based innovation. In the paper also this modelling with the help of technology knowledge transfer process is presented. The open innovation process modelled and called innovation targeting participatory research process can be used by universities and enterprises which aim for open innovation process where university has an important role as a knowledge and technology source for the enterprise. The model emphasizes committed participation and continuous dialogue.

Keywords: University, Industry, Targeted open Innovation, Technology Knowledge Transfer, Interaction, Model

Introduction

In technology development of products and productions the technology knowledge creates the base for innovations. Enterprises need to adopt the newest technology knowledge in order to develop and create new innovations. This research is based on assumption that technology knowledge transfer executed according to the plan based on need recognition enables open innovation processes between higher education institutions and industry.

This paper concentrates on targeted open innovation between a university and industry in the creation of innovations in a regional context. Satakunta University of Applied Sciences (UAS) in Finland is used as a source for the case studies to model the innovation interaction processes. The research aims at modelling and best practice process model of targeted open innovation in a local context. The model should be pragmatic and have practical implications. There will be many potential benefits of using the model for both industry and higher education.

Satakunta University of Applied Sciences (Satakunta UAS) in Finland has developed multiform interaction and open innovation processes with the local industry since 1990's. This interaction has evolved into partnerships with some of the enterprises. Typically these enterprises are significant operators in their field of industry. Partnerships are continuously developing processes, and the creation of trust is a crucial part of them. The trust between the university and firms grows with small and specific action steps. One tested way in promoting the trust is to focus on the firm's Research, Development and Innovation (RDI) actions. In these kinds of university-industry partnerships the research, development and innovation needs of the firms are constantly identified and, based on the identification, the most potential development tasks are defined and prioritized. This persistent work creates a solid base for developing RDI co-operation for targeted open innovation. (Leino and Laine 2014)

In order to develop and broaden the actions the technology knowledge transfer and the innovation processes need to be modelled. Then new operators can benefit from lessons learned from earlier actions and there is no need to reinvent the process and practices. The modelling is done for shareholders, partners and potential partners. It can be used to better understand and develop actions. In this paper the knowledge creation and flows are connected to Mode 3 knowledge creation and Quadruple Helix innovation models conceptualised by Carayannis and Campbell (2009; 2012).

The structure of the paper is the following. First the background and theories are explained. Then the technology knowledge transfer and open innovation processes are modelled and the main actions are presented with case example comparison and evaluation. The main results are summarized and discussed, and conclusions are given.

Background and Theoretical Framework

The background and theoretical framework of this research are in innovation knowledge creation theories, in technology knowledge transfer theories, in modelling, in partnerships and in best practice recognition as well as in constructive and qualitative research. In this chapter the background and the theoretical framework are described connected to references which have impacted remarkably to this research.

In the knowledge-driven economy there is a growing need for deeper and more productive interaction between higher education and industry. The full exploitation of knowledge requires strategies, incentives, appropriate processes and a strong interaction between the transferring processes and the main processes in the higher education. In a knowledge-based economy, knowledge is more likely to be created in application collaboration. In this kind of knowledge creation process, the knowledge creation, dissemination and utilization are carried out close to each other or even simultaneously. In addition, basic research and applied research can no longer be separated. Knowledge creation is discovered to be, in many cases, based on a long-term partnership where trust, commitment and mutual benefit can be achieved. (Laine 2010.)

Modelling of innovation in this research focuses on processes which aim at the creation of innovations by creating new valuable combinations of internal and external knowledge. The research will use mixed methods by combining qualitative and supporting quantitative methods and process modelling. Innovation management research typically models the development paths of the idea, the people and organizations involved in the interactions and the transactions between the operators, the outcomes of the innovation process, and the context of innovation. Although innovation paths are individual, general elements suitable for most similar processes are presumably discovered (Tidd et al. 2005; Van de Ven et al. 2008).

In this research the modelling is based on experimental steps executed with enterprise partners:

1. technology needs of the potential partners are recognized
2. draft of the model phases is created by the university
3. draft is introduced to the enterprise partners
4. detailed model is created by experimenting the drafted steps

Innovation is often understood as the implementation of a new or significantly improved product, or a process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations. In this research innovation is understood as a new valuable combination of the organisation's internal knowledge and knowledge from external sources.

Innovation is changing from a closed innovation paradigm to an open innovation paradigm (Chesbrough 2003; Chesbrough et al. 2006). Closed innovation referred to doing Research and Development (R&D) and innovation related activities in-house. The open innovation paradigm considers external ideas and exploiting opportunities as equal to an organisation's own ideas and ways to commercialise them (Chesbrough 2003). In the open innovation paradigm higher education is an important collaboration partner for firms (Ibid). In knowledge society the knowledge is more widely distributed. Open innovation is about finding new creative combinations of internal and external knowledge (Ibid). Open innovation seems to be applicable in a growing range of industries (Vanhaverbeke 2006; Gassmann et al. 2010).

There are three types of open innovation processes

1. outside in, where outside knowledge and technology are brought into enterprise to create innovations
2. inside out, where enterprise's own and outside channels are used in parallel to bring innovations to the market
3. combination of inside out and outside in processes (Gassmann and Enkel 2004).

Open innovation gives more opportunities for enterprises than closed innovation. In many cases it gives too many opportunities. This forces enterprises to focus their innovation actions. Targeted open innovation process is defined as an innovation process where organisation's strategies, competences and market knowledge are used in defining and selection of innovation targets and process models.

Innovation is mainly based on knowledge. Therefore learning and knowledge management are involved in the innovation process (Cohen and Levinthal 1989). Knowledge management can be seen as strategies and practices used in an organisation to identify, create, represent, distribute, and enable the adoption of insights and experiences. Knowledge management should support the accumulating and creating of new combinations of knowledge in interaction that aims to the creation of innovations. The absorption capacity is defined as an ability to recognise, acquire and use useful knowledge (Cohen and Levinthal 1990).

Etzkowitz & Leydesdorff elaborated the Triple Helix model of university-industry-government relations in 1995 (Etzkowitz & Leydesdorff 1995). It has been one significant model for designing and implementing local collaboration between higher education, industry and civil service since. In practical implementations the triple helix model appeared to be incapable to include many equal partners to open innovation. This led to the next stage of quadruple helix innovation. Quadruple helix innovation states that also civil society should be included in open innovation processes (Ahonen et al. 2012). Today universities do not only give an input to innovation but they are embedded in it (Etzkowitz 2014). Universities have to be entrepreneurial and create their own responses to the changes of society (Galan-Muros et al. 2014).

Knowledge creation and innovation processes are complex, nonlinear and dynamic. Mode 3 emphasises simultaneous existence and evolution of different knowledge and innovation paradigms. "The competitiveness and superiority of a knowledge system is highly determined by its adaptive capacity to combine and integrate different knowledge and innovation modes via co-evolution, co-specialisation and co-opetition knowledge stock and flow dynamics" (Carayannis and Campbell 2009). Quadruple helix emphasises integration of media based and culture based view to Tripple Helix. Model of nonlinear innovation models brings knowledge production and use, universities, university related institutions, academic firms, and commercial firms into interaction. These all constitute a Mode 3 innovation ecosystem. Knowledge waves refer to creation of knowledge and flows transitions between actors. (Carayannis and Campbell 2009; 2012.) In this research the focus is in knowledge based innovation. See four-fold typology of interaction between knowledge and innovation in Carayannis and Campbell (2009).

Mode 3 emphasises five key elements: GloCal (global-local) multilevel innovation systems, cluster as elements of the system and networks as rationale of the system, knowledge clusters, innovation networks and co-opetition, knowledge fractals, and finally adaptive integration and co-evolution of different knowledge and innovation modes (Carayannis and Campbell 2012). This leads to parallel existence of linear and nonlinear knowledge creation. Heterogeneity and diversity of disciplines requires fostering of creative knowledge environments. Different actors and agents are needed. Innovation is evolutionary and learning based.

Innovation management refers to management of strategy, process and networks of new ideas and their utilisation. Innovation is closely connected to learning and therefore innovation can be enhanced by using knowledge management to support knowledge creation and combination. Learning and expertise are also connected to innovation because knowledge intensity increases in society and in products as well. Experts cross borders in their work and therefore they have opportunities to create innovations. And vice versa, the creation of innovations requires actions that are typical for experts. (Tidd et al. 2005.)

Innovation takes increasingly place in collaboration, networks and clusters leading up to open innovation. In open innovation, higher education is an important innovation partner for firms. New practical models are needed to enhance collaboration in innovation to harvest the benefits of open innovation. This is also important to enhance the combination of science and practice based innovation. According to Nonaka and Takeuchi (1995), knowledge creation is a process where experience based tacit and writing based explicit knowledge interacts. (Laine 2010). Knowledge intensity emphasises the importance of learning for individuals, organisations and innovation systems (Nonaka and Takeuchi 1995; Senge 1990; Kaplan and Norton 1992; Lundvall and Johnson 1994).

In 2007 Perkmann and Walsh concluded that traditional technology transfer between universities and enterprises has focused mainly on IP rights, patents, licensing and commercialization of the research results whereas the modern technology knowledge transfer means much wider actions with different operation channels and mechanisms. These channels and mechanisms are used to describe cognitive and social paths of knowledge, information and other resources' dissemination and further development in collaboration between enterprises and HEIs. (Perkmann and Walsh 2007)

Technology transfer has come to its turning point in the 2020th century. Bradley et al. bring out insufficiencies of traditional, linear technology transfer. They also point to increasing importance of technology transfer for economic development and innovation. Universities must create their own technology transfer models to support and boost their research activities in order to better exploit them with the enterprises. (Bradley et al. 2013)

In this paper a partnership is defined as a long lasting collaboration between organizations in order to solve strategic challenges. A model is defined as a simple description of a system or process to describe how it works and to show its essential elements. Evaluation is judging the value or the condition in a careful and thoughtful way (Merriam-Webster dictionary). A process is defined as a series of actions that are performed in order to achieve a particular result.

Best practice is a method or technique that has consistently shown results superior to those achieved by other means, and that is used as a benchmark. Best practice can evolve to become even better as improvements are discovered. Best practices are used to maintain quality as an alternative to standards and can be based on self-assessment or benchmarking. Best practice can be used to develop and unify practices, learn from them and to share practices with others.

In Finland the main drivers of University Business Collaboration (UBC) are mutual trust, short geographical distance, prior relation to the business partner, mutual commitment and a common interest of the stakeholders. The main benefits of UBC identified by Finnish academics are: improved employability of future graduates, improved learning experience for students, improved reputation in the field of research, increased funding and the improved performance of a business. The main barriers to UBC in Finland have proven to be: differing time horizons between a university and a business, the limited absorption capacity of SMEs to engage work placements or projects, the businesses' lacking awareness of the university research activities/offerings, the lack of financial resources of the business and the lack of university funding for UBC. The main benefits of UBC have been identified by the representatives of the Finnish HEIs (Higher Education Institutions). According to them, UBC is seen vital in achieving the mission of the university, in improving the skills and graduate development. Furthermore, UBC has beneficial effects on the local industry, it increases local GDP and disposable income, and it creates local employment. Supporting mechanisms may be strategies, structures, approaches and activities. In Finland it is typical to have documented strategies with implementation plans. Collaboration is role-based and there are internal and external agencies focusing on it. Activities are, e.g. workshops for academics and students, networking, and promotional and project activities. (Davey et al. 2013; Leino and Laine 2014).

There are several reasons for developing interactions between higher education and industry. Practices change. It has been noted that collaboration matters. However, new ways to collaborate are searched. There is a need for more operative and goal focused collaboration between HEIs and industry. Earlier, industry was curious and wanted to see if collaboration had something for them. Nowadays there is no longer time for these kinds of open ended processes. Industry wants to define what they want as output and outcomes from the collaboration, and this definition steers collaboration. Our assumption is that HEIs should set their own goals as well and clarify them in the beginning of collaboration to avoid confusion and mistakes in collaboration.

Models presented in this paper are based on true innovation collaboration and processes between Satakunta University of Applied Sciences and Industry. Satakunta UAS has executed these processes with ten enterprises in ten cases during last seven years. Most of the cases have several enterprise participants. Processes have been modelled. Comparisons have been done between cases and best practices have been identified. Models have then been simplified and generalized to create process models that present the crucial elements and suit for most of the cases.

The main view of interest in this paper is the higher education's point of view. The emphasis is in the beginning of the innovation process where search and combination of different knowledge sources are central. The core research question is: how to support new combinations of user and application based knowledge, technological knowledge and scientific knowledge. The aim is to model these combination creating processes to one innovation generating entity.

The research is constructive in its nature. Constructive research is an applied research method and means problem solving in forms of construction of models, diagrams, plans and organizations, for example. It is widely used in technical research, but also on other fields like mathematics and clinical medicine (Kasanen et al. 1993). The process of constructive research is the following although not always in the same order

1. Find a practically relevant problem
2. Obtain a general and comprehensive understanding of the topic
3. Innovate i.e. construct a solution
4. Demonstrate that the solution works
5. Show the theoretical connections and the research contribution of the solution and
6. Examine the scope of applicability of the solution. (Kasanen et al. 1993)

The realization of a new construction is an accomplishment in itself. Effectiveness and impact are the central measurements of the realization on the construction (March and Smith 1995). The results of constructive research can also be judged by relevance, simplicity and easiness of operation (Niiniluoto 1985). The results are often empirical and normative, leading to suggestions (Kasanen et al. 1993). Truthfulness can be used as a criterion for the validation of constructive research but primary the criterion is its practical usefulness, the market based validation. Market based validation can be divided into three categories. A weak market test applies when some actors are willing to apply to the construction. A semi strong market test to the construction applies if the model is widely adopted. Finally, a strong market test applies if the construction systematically produces better results than not using it would. Even the weak market test is a strict test. (Ibid)

Constructive research must have both practical relevance and theory connection. A construction is a solution to a selected problem. The construction usually has both practical implications and theoretical contribution. The innovation phase is heuristic by nature; stricter theoretical justification and testing of the solution often come afterwards (Kasanen et al. 1993). Most constructive research use case studies (Eisenhardt 1989).

Qualitative approach can be used to create a deeper understanding of the phenomenon under examination. The main goal is to understand the phenomenon more deeply to be able to develop it further. The aim is not to make large generalizations of other environments. Qualitative research requires theoretical sensitivity from the researcher. (Yin 2003; Eisenhardt 1989). The research will use mixed methods by combining qualitative and supporting quantitative methods, process modelling and network analysis. Innovation management research typically models idea development paths, the people and organizations involved, interactions and transactions between actors, the outcomes of the innovation process, and the context of innovation. Although innovation paths are individual, general elements fitting to most similar processes are supposed to be found (Vand de Ven et al. 2008).

The researcher of qualitative research should not rely only on documents and interviews in case studies but also on observation (Silverman 2007). The source of evidence in the case study is documentation, archival records, interviews, direct observations, participant observations and physical artefacts (Yin 2003). There are three principles in collecting evidence: use multiple sources of evidence, create a case study database and maintain a chain of evidence from research questions to conclusions and back (Ibid). There will be several sources of research data. Observations, interviews and process modelling will be used as primary sources. Documents will be used as a secondary source. Case study process tools like comparisons will be used inside the cases, between the cases and to other actors and models (Yin 2003; Eisenhardt 1989). The researcher will also be involved with projects and interaction in practice. The projects will serve as platforms both for model creation and verification. Experimentation and testing of created models will be done in a real environment.

Several potential theories and concepts will be examined for the study. This research will use the organizational level, and not the personal level, as its outlook. Although legal and immaterial property rights and other legal issues are important in innovation, they will not be covered in this paper. The paper will model technology based and knowledge transfer based interaction with SMEs. It will not cover licensing. It will be interested in interaction models where technology teachers, researchers and students are in central roles and the goal is to create targeted open innovations with enterprises. This research does not cover pedagogy theories except when taking into consideration that when students participate in the interaction it will support the building of their expertise and core competencies.

The research will use the framework of innovation management and it will be based on a broad conception of innovation. In this conception innovations are embedded in social activities. There are many useful types of innovations besides radical technological innovations, like incremental, disruptive and systemic innovations. Innovation is closely linked to learning, and tacit knowledge has an important role in innovation. Innovation is a complex process and innovation diffusion is important in addition to innovation creation. Innovation is a collective undertaking and networks are essential for it. (Toivonen 2004) In the research a system approach will be used. In a system approach general conceptual and abstract structures and parts are described. A system is described as models that are simplified and subjective descriptions of the phenomenon. Therefore the models are not exact, objective copies of the reality. Models are described as a system with interrelating parts.

Technology Knowledge Transfer an Research Implementation

One main goal of this paper is to describe how systematic technology knowledge transfer based on recognized needs of the enterprises will foster the targeted open innovations. The technology transfer actions of this research are presented in this chapter.

One key issue in long-term success of a technology enterprise is innovation creation. This means technological development of new products, production processes as well as adoption of new business models. It requires continuous search and selected adoption of new technological knowledge.

Especially SMEs do not usually have enough resources to search new technologies and technological solutions for themselves. They often would benefit from independent experts to act as drivers, which enable the collection of complex and fragmented pieces of the latest technology knowledge and its transformation into useful knowledge for the development of production and business activities of SMEs.

Enterprises may use large amount of resources to consider how to develop their processes or e.g. which technology could be the right choice for the new or improved product line. With assistance of a specialized expert the knowledge needed for the decision making processes could be more easily achievable than by searching the knowledge by themselves. This requires that the enterprise must know the suitable experts in the scope of its operations.

Universities have wide range of experts in their personnel. In Finland the Universities of Applied Sciences have technology experts with technology knowledge transfer competence and education ranging from Master of Science to Doctoral degrees. UAS teachers and researchers also know the local enterprises and their field of business. This combination is bases for a collaboration but it requires a practical operational model. Satakunta University of Applied sciences has created, piloted and tested a multidimensional process model for technology knowledge transfer. This process model is used when Universities of Applied Sciences scan, search and interpret international technology knowledge for SMEs. In this paper the main focus is in actions and collaboration executed by university and enterprise personnel. At the same time in this whole concept the students have a remarkable role in all of the operational actions.

The international technology knowledge transfer process model consists of all the steps needed for searching latest international technology knowledge and interpreting it so that the local enterprises can benefit from it. The model makes it possible for the enterprises to benefit from the knowledge searching competence and international network connections of the university. All targeted goals of the technology knowledge search are coming from the enterprises. This way they may benefit from the knowledge as straightforwardly as possible. All the searched knowledge are meant to answer to the specific questions coming from the enterprises.

In brief, in this technology knowledge transfer process the knowledge search goes on in two phases. In first phase it is wide-ranging. Focus is in new innovations, technological changes, standard and regulation changes and in suitable sources of knowledge, like research publications, conferences, events and seminars. In the second phase the focus is in deeper and more precise cases which have been sifted from subjects of the first phase. In both phases the knowledge search consists of many actions executed simultaneously.

The knowledge search is done in expert teams. The expert teams can be seen as small knowledge clusters defined by Carayannis and Campbell (2009; 2012). The teams are exploiting their existing national and international networks and also creating new contacts to universities, research centers and their company networks. Focused dialog between experts and company representatives is the base for productive knowledge search. In that way the best detected potential knowledge sources and knowledge transfer methods will be utilized. The plan for knowledge search must be updated regularly. The knowledge searching teams test several different methods in communication and knowledge transfer so that it would be possible for different kind of learners to adopt knowledge.

Technology Knowledge Transfer Process Model

The technology knowledge transfer process model is created by testing and piloting different phases and steps. The draft of the model is based on five steps:

- Need recognition

- Knowledge search plan
- First knowledge search cycle
- Detailed knowledge search
- Evaluation

The technology transfer process is executed according to the draft. After every step the best practices are detected and the detailed phases of the step are documented. The final model is constructed by combining the steps with detailed phases. Fig1 describes the main steps and phases of this model. The steps will be explained further in the next sub chapters.

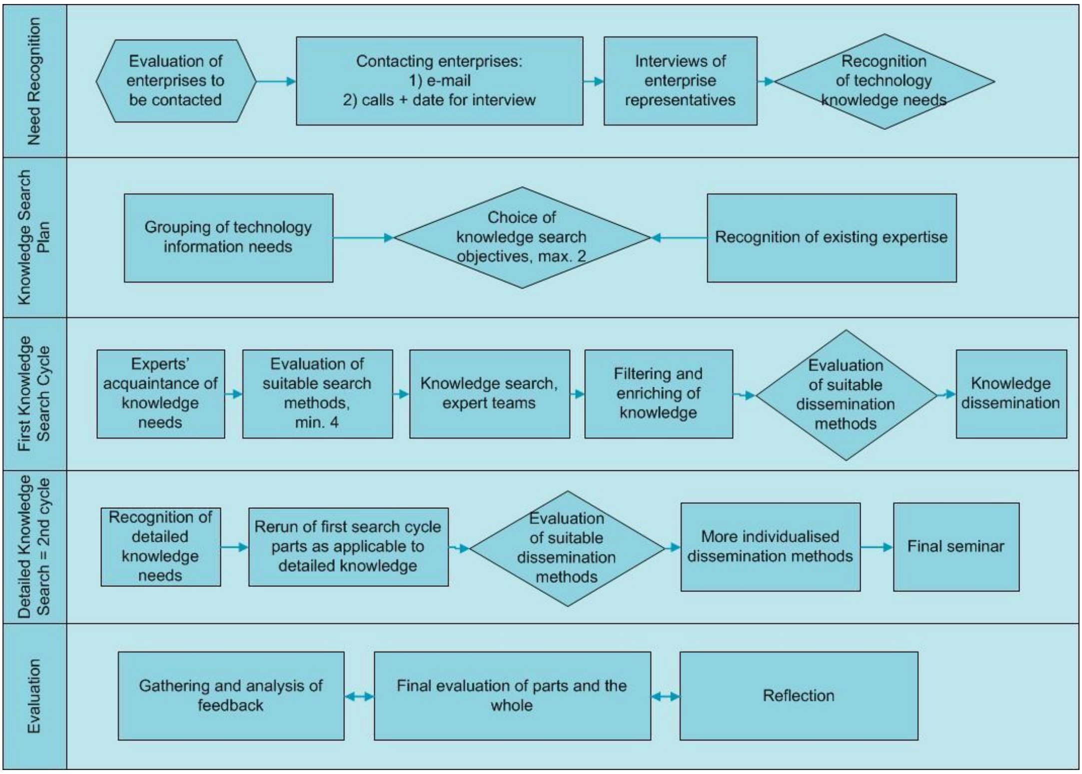

Fig 1 The process model of international technology transfer

Each step of the model consists of process phases, which all have to be implemented in presented order to reach appropriate results.

Need Recognition

Need recognition in this model refers to the preliminary work, which begins with the evaluation of the enterprises. At first, it is essential to choose the field of industry and size of the enterprises accepted in the project as well as their geographical location. The enterprises recognized by the evaluation are first contacted by email with explanations of the aim and operational methods of the technology knowledge transfer process.

The need recognition interviews are one qualitative research approach in this technology knowledge transfer research. The interviews must be properly prepared for. There should always be some suggestive questions, but it is of utmost importance to see during the interviews that the questions are suggestive only and that the enterprise representatives have a true opportunity to describe their problems and knowledge needs. The main subjects of the discussions will be written down and a document including the progression plan will be sent to the enterprise to be accepted. The progression plans have to be made considering the whole of the knowledge search and technology knowledge transfer but also take carefully into consideration the wishes expressed in the interviews. After all of the interviews of the interested enterprises the expressed needs for knowledge will be analyzed.

Knowledge Search Plan

During the second step a knowledge search plan will be made. Making of the plan begins by grouping the technology knowledge needs expressed in the interviews into a few groups under a main objective. The amount of different objectives should be carefully considered because the more there are objectives the more wide-ranging the knowledge search will be. If there are more objectives, there must be significantly more experts working for, which further increases the need for financial resources. One demonstrated knowledge search proved that with two interrelated main objectives a team of four to six experts can keep the activities straightforward.

The choice of the main technology knowledge search objectives is very much affected by the expertise of the researchers and teaching staff of the university. The recognition of existing expertise and recruitment of these experts in the project is the absolute key issue of the project plan feasibility. When the technology knowledge needs of the enterprises found in the need recognition process and the existing expertise meet, the knowledge search plan can be made with good chances of success.

Initial Knowledge Search Cycle

The knowledge search should begin with the experts acquainting themselves with the technology knowledge needs chosen for knowledge transfer. Thus the experts get the most efficient start for the work. After this the knowledge search methods that best suit the objectives and the experts will be discussed in groups.

The knowledge search process begins as follows. The knowledge search is carried out by expert teams founded around each main objective. As regards the expert teams, the two most important issues are to have a nominated person responsible for each main knowledge search subject, and to have team members participating in more teams than one. Teams with partly common members communicate more fluently and thus avoid overlapping work, especially with objectives close to each other.

The experts will filter the essential out of the retrieved knowledge based on the questions and knowledge needs stated by the enterprises. Simultaneously with the filtering the knowledge is also interpreted so that it is easy for the company representatives to adopt and use it at their work. The construing is both linguistic and, most importantly, making the technological novelties more intelligible.

When the knowledge and answers have been retrieved, filtered, and examined, the dissemination methods are decided in order to disseminate the knowledge for the cooperating enterprises. Especially seminars with one or two top-ranking experts and the responsible experts from the university speaking in first language of the attendees have turned out to be successful. The top-ranking experts should be chosen, according to knowledge needs, to speak about their own special field, and the responsible experts represent the wider results of the knowledge search. Other first phase dissemination means include electronic knowledge packages and workshops, where it is possible to record the needs for more detailed knowledge. The chosen means of dissemination are carried out so that in addition to shows and discussions the participants will receive written material to which they can refer later on.

Search for Detailed Knowledge

The second knowledge search cycle begins with discussions with the enterprise representatives. The main goal of these discussions is to recognize the needs for detailed knowledge. These needs have turned out in the first knowledge search cycle and in connection with problems that have potentially arisen elsewhere. The detailed knowledge search is carried out in quite a similar way to the first cycle, only now the focus is on individual international knowledge sources, identified during the project. At this point it is even more important than before to visit the knowledge sources, because the pilot project indicates that the best and most feasible knowledge is retrieved in face-to-face discussions and by getting to know the possible research infrastructure.

Again, after detailed knowledge search the dissemination methods must be decided. According to the enterprise feedback the seminar afternoons consisting of expert lectures and written material are a very good methods in reaching as many enterprise representatives as possible. Expert lectures on all main objectives may be given at one seminar like the final seminar of the technology knowledge transfer, but more seminars may be held as needed. It is also beneficial at the end of the knowledge transfer work to contact the enterprises one by one, giving out the most individualized expert statements at the same time.

Evaluation

According to qualitative research method evaluation of this kind of a technology knowledge transfer process is very important since it increases and refines the skills of the participants as all counterparts give feedback on the implementation of the project. Feedback from enterprises is usually retrieved with a generally used post project evaluation method of the university. In the feedback it is important to define the project aims to the respondent, to ask their opinion on the project outcome and whether they have identified any benefits, and to find out their will to continue cooperation. There must also be an opportunity for open commenting in the feedback.

The technology knowledge transfer implementers should reflect the work as a whole and perhaps its steps also. The aim of the reflection is to observe the things that were learned and experienced during the knowledge transfer process. What was learned concerning knowledge search objectives and our activities during the process? How was knowledge retrieved and how was it filtered and interpreted? How did expert groups and teams work? How was the expert cooperation like? Which issues were successful in the process? What could have done better? What kind of feelings of learning and hopes for continuation did the work rise? Reflection gives the implementers a chance to develop themselves and the technology knowledge transfer activities of the organization.

Based on the reflection and feedback from the enterprises evaluations of the whole technology knowledge transfer process and its steps can be drawn together. The evaluation promotes the planning of further actions and research and development activities.

Technology Knowledge Transfer - Case Comparison

In the previous subchapter the technology knowledge transfer case evaluation was described. In this subchapter the cases and the evaluation results are compared with each other. Case descriptions were partly created during the cases and descriptions were finalized afterwards. The comparison is made by listing the steps of the processes and the success factors and challenges identified during the processes. In Table 1, four technology knowledge transfer cases are presented according to this comparison.

Tabel 1 The technology knowledge transfer case evaluation and comparisons between cases (based on Leino et al. 2012 and findings in this research)

Case	Level of Identified Knowledge Need	Steps	Challenges and Success factors
Infrared (IR) Imaging in Real-Time Quality Control of Welding	Could the defects in welding be recognised with machine vision?	Literature study Dialogue with the enterprise representative due to the study Search for more detailed knowledge IR imaging tests and demonstration for welding	Challenges in combining IR machine vision knowledge with welding knowledge Many identified possibilities to IR image faults in welding
Machine Vision in Quality Control of Veneer	Could the veneers coming to furniture production be classified with machine vision?	Literature study Dialogue with the veneer classifier person Search for more detailed knowledge Near Infrared (NIR) imaging and Near Infrared Spectral (NIRS) imaging tests and demonstrations for veneer classification	Classification is made by humans -> there are no clear classification methods Every veneer is different and boards are too large for one imaging system with these resolutions Test showed that classification system could be designed
Possible Methods for Nail Quality Control	Could the quality control of nail be done with machine vision	Literature study Search for similar applications Dialogue with the enterprise representative due to the study Machine vision tests and mechanics demonstrations	Complex and fragmented entity Lack of mechanics expertise Experimentation based innovation Tests and pilots made it possible to innovate
Machine Vision for meat food industry (Kortelainen et al., 2014)	What kind of machine vision systems are applied in meat food industry	Literature study Search for piloted applications Dialogue with the enterprise representative due to the study Detailed knowledge search Report and presentation of the identified applications	Completely new area of industry Piloted applications are not so often exhibited Many application examples were found Advantages and challenges of different imaging techniques were identified and interpreted to the enterprise

Identified challenges were case specific. Most of the challenges were related to the subjects and combination of knowledge. Success seem to be based on systematic process and on clear targets identified in interaction.

From Technology Knowledge Transfer to Targeted Open Innovation

It is one thing to search and find technology knowledge and transfer it to the enterprises as interpreted and enriched knowledge. It is much more demanding process to create targeted open innovations according to the new technology knowledge. It demands deeper collaboration and shared research interests between enterprises and universities. In theory, open innovation gives more opportunities for enterprises than closed innovation. In practice, it gives too many opportunities. This forces enterprises to focus their innovation actions. When seeking new possibilities through open innovation processes the enterprises tend to overreact and wish to cover many challenges at the time. These situations are good examples of potential quadruple helix innovation processes.

When the collaboration is based on mutual trust created in partnerships it is possible to accomplish constructive dialogue which leads to targeted open innovations. Above presented technology knowledge transfer processes executed according to the plan have led into versatile dialogue with partner enterprises of the university. These dialogues and targeted open innovation processes following them have been modelled as Innovation Targeting Participatory Research Process showed in Fig2.

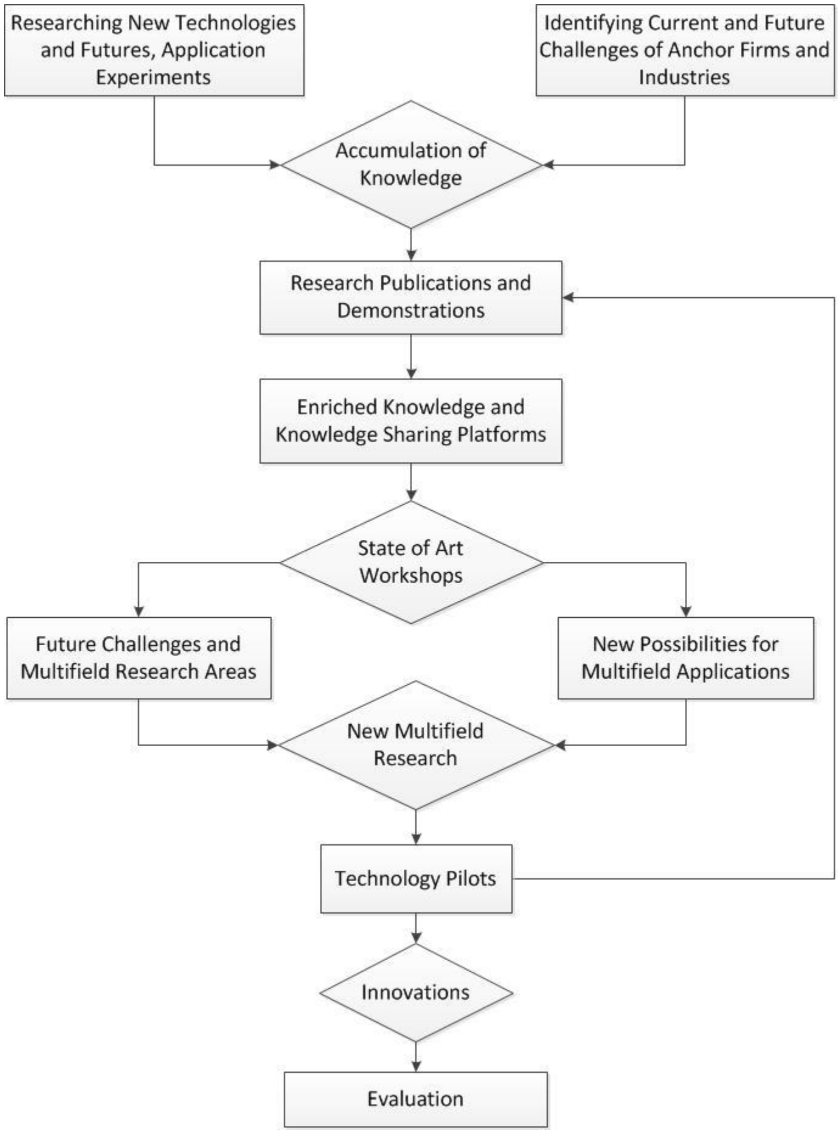

Fig 2 Innovation targeting participatory research process

Innovation Targeting Participatory Research Process

Innovation targeting participatory research process aims to new targeted open innovations. The process starts interlocked with technology knowledge transfer process. Main outcomes of the technology knowledge transfer processes are the results of researching new technologies and futures and also application experiments done according to the research. These outcomes start the innovation targeting participatory research process. At the same time the current and future challenges of the anchor firms and industries are identified. The anchor firms in this context mean e.g. the partnership enterprises with trustful relations with Satakunta University of Applied Sciences (Leino and Laine 2014).

The targeted accumulation of knowledge can be started when the technology challenges and knowledge needs have been identified. As results of accumulation, like feasibility studies and reports, research publications and technology demonstrations are designed and executed. These results are then used to enhance the knowledge and shared on knowledge sharing platforms. The state of art workshops are organized to ensure that the enterprises identify the possible collaboration opportunities. In the workshops the most important results of the accumulation are presented combined with technology demonstrations. The goal of these workshops is to find and name the most potential innovation targets for the collaborative research. The workshops make the enterprises to participate stronger and to bring their own ideas to the participatory research process.

In addition to more participatory research collaboration the workshops also generate future challenges, multi-field research areas and new possibilities for multi-field applications. All these are identified by combining challenges of the enterprises and knowledge and know-how of the university. Targeted research subjects and application needs are identified in this process and they lead to more outlined research and that way to clearly targeted open innovations.

Case Evaluation of Innovation Targeting Participatory Research Processes

In table 2 the innovation targeting participatory research cases are evaluated and compared.

Tabel 2 Case evaluations of Innovation targeting participatory research processes

Case	**Initially Identified Knowledge Need**	**Workshop Results**	**Targeted Open Innovation**	**Evaluation**
Smart Cameras Guiding the Robot in Re-bar Net Cutting	Potential ways to guide the robot in re-bar net cutting process	Identified machine vision possibilities	Smart camera based machine vision system for guiding the robot	First innovation targeting participatory research process executed in SAMK generated lots of ideas to develop the process model The final innovation was developed in 2011 and has been working independently since then
More Automated System for Measuring Reinforced Bar (Valo et al. 2013)	How to automate and make the measuring process more accurate and repeatable	Potential machine vision techniques identified	Intelligent 3D imaging system based on multiphase silhouette imaging for measuring reinforced bars	Inclusive innovation targeting participatory research process with multiple feedback circles Targeted open innovation in initialization
HIL Classification of Blood Serum (Kortelainen, 2013)	Is it possible to classify Hemolysis (H), Icterus (I) and Lipemia (L) in blood serum with machine vision?	Potential machine vision techniques identified	Pilot system for classifying HIL values in blood serum	Innovation targeting participatory research process with both operator and developer

Evaluation of these cases proved that in targeted open innovation processes of Universities tight participation of the client enterprise is crucial. When it has been taken into consideration the cases have been successful. The innovation targeting participatory research process model has been enhanced according to these cases.

Main Findings and Discussion

This paper models two types of targeted open innovation processes. The first one is a focused technology knowledge transfer process. The second one is a targeted open innovation participatory research process. The processes are different and for different situations, but they overlap. The first process, focused technology transfer process, creates often new seeds or starts for targeted open innovation participatory research process.

As described earlier, the technology knowledge transfer process starts by listening the knowledge and technology needs of the enterprises. Then the cases matching the competence of the research teams are selected. In the targeted open innovation participatory research process the research teams introduce their competence for the enterprises and then the enterprises can decide how they would like to utilize the competence and networks of the research teams. In this process the competences are introduced with technology demonstrations which make it easier for the enterprises to figure out what kind of opportunities the technologies offer.

According to our research, there may not be enough resources for systemic knowledge search and problem solving in SMEs. If there is or if it is supported by external expertise the decision making is definitely easier when there is more comprehensive and research based knowledge about the problems to be solved. For universities these kind of targeted open innovation processes are important because they can make their applied research target based, involve teachers, researcher and students into the processes and develop new competences in them. The university can add its impact to the region and make new research contacts widely. The enterprises benefit from focused knowledge by implementing it in their business. They may also benefit from the created process models with other actors and have the courage to develop new processes with other actors as well.

Evaluation of cases proved that trust based and committed participation of the partners is crucial in targeted open innovation processes of universities. When enterprises have fully adopted the participatory process model the cases have been successful. External R&D can create significant value but internal R&D is needed to claim a portion of that value (Chesbrough 2003). The innovation targeting participatory research process model has been improved according to the cases. However, it is challenging to make this process model understandable and visible so that all the actors have the possibilities to exploit it in their work. It is important for the enterprises to take notice to the targeted open innovation processes and knowledge of the universities and to adopt participatory action model in order to utilize it. The process uses both tacit and explicit knowledge of actors, so trust creation is essential. It takes time to create trust and therefore it takes time to benefit from the created processes in full scale.

A sign that shows that the innovation network is actually developing is that its members create new practices together. In the researched cases this seems to be true. Partner organizations are satisfied with the amount and type of actions, systematic approach in the open innovation process, the research knowledge based on their own process data, and the documentation of the results. As a partner organization representative stated in a board meeting: “It is easy to make decisions now because we have real knowledge about the subject”. The processes have helped the partners to solve several problems, create new products and services and to make investment decisions based on knowledge.

The most important issue in these projects is that they give the enterprises a wider and supplier independent information of the potential technologies to use for their innovation targets. At the same time the researchers and students add their experience of real-life research, development and innovation cases. Enterprises build their innovation networks and add their absorption capacity as well. It seems that executing outside in part of open innovation process well gives opportunities to do well in inside out innovation process and in combining them. Comprehensive knowledge scanning, development of market insights, prototyping and patenting processes are knowledge intensive phases and help in adopting new knowledge that helps in other parts of open innovation. When experimenting different types of model and transferring between them, it is important for the enterprises to keep a clear target in mind. Otherwise, they may lose their focus and end up expanding their knowledge and technology base. Therefore utilization of the knowledge and technology becomes less effective.

University can utilize students in innovation processes with enterprises. In practice, cases vary a lot from small technology search or feasibility study to research projects done by the researchers of the university. This adds agility and flexibility to respond to different needs identified in the enterprises. At the same time it gives real life content to studies. (Leino and Laine 2014.) The future goal is that all the engineering students will participate in technology oriented targeted open innovation processes with the enterprises. That way they have more chances to enhance their practical project and technology development skills during their studies.

The following best practices were identified in the processes. Firstly, two phase knowledge search for enterprises where the knowledge found is evaluated with the enterprise before the more detailed knowledge search. In practice the evaluation is continuing during the process in parallel with the search. Secondly, the illustration of opportunities with technology demonstrations is important. Thirdly, in piloting the equipment can be installed in real environment in enterprises so that enterprises can see themselves the performance and capacity of the new technology. Fourthly, one essential question for the university in the future is how to develop the process so that also the university is actively setting its own goals already in the beginning of the process to ensure actions that create the needed results for the university. This should lead to wanted results for universities as well.

Accumulation and building of knowledge is done in collaboration between university and enterprises. Therefore active individuals among students, researchers, teachers and enterprise personnel are in crucial role. Tacit knowledge of participants is combined with explicit knowledge. Especially tacit knowledge of the enterprises is combined with explicit research knowledge to solve the problems prioritized. Therefore continuous dialog between actors is essential. Enterprises need to have their own R&D simultaneously. It is not appropriate to outsource knowledge search and R&D completely because own R&D helps to benefit from.

The research supports Mode 3 knowledge creation, quadruple and quintuple innovation systems. It is a practical example of how knowledge creation starts from nonlinear mode, but interacts and benefits from linear knowledge creation (Carayannis and Campbell) and uses them in parallel. It benefits the different knowledge waves and flows and accelerates them by creating knowledge creation environments and interaction between different actors. Although knowledge clusters in this research were local, the knowledge was searched in international networks and enterprises and local networks met global competition. This emphasised systemic approach that was needed in innovation processes. Public domain and environments were used in the process as well. Some of the created knowledge was shared in open workshops and seminars. This was not only to share the knowledge but also to change the culture towards open sharing of processes between universities and enterprises. Learning is an important part of evolution in short and long time scale.

Conclusions and Recommendations

In this research the two open innovation processes between the university and industry was described and evaluated. Both the university personnel and the students and the personnel of the partner firms seem to learn a lot in the collaborative actions. There are several benefits, e.g. new learning outcomes and the need-based competence development of personnel. However, partnerships require constant development of the processes and the actions. A lot of feedback concerning university processes is available. Partnerships help to create targets for open innovation processes and to create research-based knowledge to support innovation processes in industry. Open innovation processes foster new innovation creation and open eyes to see new opportunities for future collaboration. It is recommended that higher education sets its own goals from its own point of view and sets the goals already in the beginning of the process. Then it can be equal partner for industry when both have their set goals. The innovation processes can be improved almost endlessly although it is not obvious that the improvements are able to be generalized. Sometimes improvements fit only for specific cases.

The research has implications for both theory and practice. The created models can be utilized in the management and creation of innovations in collaboration between the higher education and industry. The modelling is a generalization since it is a simplified description of reality and the research tried to capture the most essential parts of the phenomenon. The research was found to have several practical implications. The results can be generalized to similar environments and organizations, yet they should be used with care because the initial conditions also affect the results that can be achieved.

In the research the process of constructive research was followed. Firstly, a relevant problem was found. Secondly, a general and comprehensive understanding of the topic was obtained. Thirdly, a construction of the solution was created as the model for technology knowledge transfer and as the model for innovation targeting participatory research process. Fourthly, it was demonstrated that the solution works by presenting outcomes and the impact of the model. Fifthly, theory connections and the research contribution of the solution were shown, and finally the scope of applicability of the solution was examined. The research followed the process of constructive research presented by Kasanen et al. (1993).

The created models are useful in practice. They can be used in guiding and developing of actions and in evaluation as well. Some parts of the model passed a weak market test and some passed the strong market test. The results were clearly better when using the model compared to not using the model. The created model, construction, is a combination of evaluated and tested best practices identified during the research process. The research had both practical relevance and theory connections. Thus the results fulfil the criteria of constructive research. As an entity the research process can be seen as successful although the usage of the results by other actors and researchers will finally show the quality of the results.

Learning is a central element of innovation in organizations was found to be true in this research (Nonaka and Takeuchi 1995; Lundvall 1992; Etzkowitz 1998; Laine 2008; 2009). This also emphasizes the importance of absorptive capacity (Cohen and Levinthal 1990; Zahra and George 2002; Laine 2008). Some earlier research propose that firms which collaborate with university scientists can have superior search for new inventions and it provides advantage in terms of both the timing and quality of search outcomes as well (Fabrizio 2009). Learning, higher order learning and dynamics are also embedded in Mode 3 knowledge production systems (Carayannis and Campbell 2012). The research strongly supports this. Research also shows how different knowledge flows and modes can and should be utilised in effective knowledge and innovation creation.

Managing the outside in open innovation processes well seems to give enterprises opportunities to manage the inside out processes well, too. Partnering and trust based collaboration helps to recognize needs and create targeted open innovations. The success of machine vision researches done according to the innovation targeted participatory research process proved that a detailed model and explicit following of it creates results. This kind of collaboration with need recognition and technology knowledge transfer also helps SMEs to start their own targeted open innovation processes. Processes add the SMEs absorptive capacity as well.

The future research should focus on how enterprises can combine described targeted open innovation processes to their other open innovation processes to add impact of their actions.

There are limitations for this research. Local collaboration was done in one region in one country. The research was done on certain fields of technology and with existing enterprises on traditional fields of industry. There is no proof how the process would work with dynamic start-ups, for example. One of the cases was interrupted during the research. The enterprise was not able to produce its own part of the process because of changed organisation. Other cases supported the created model although there were delays in the process in some cases. In many cases the researchers had several new ideas how to proceed but enterprises were usually satisfied with the first detected business case.

It would be beneficial to make similar research in other knowledge creation environments and cultures and with modern fields of industry, like dynamic start-ups and ICT enterprises. It would also bring additional value to have larger knowledge clusters and more universities in knowledge creation collaboration. It would also create new views to start with Mode 3 conceptualisation and Helix models to add new knowledge and innovation creation opportunities. It may not bring new views to the theory, but it would certainly create new avenues for knowledge and innovation creation in collaboration and full utilisation of all existing models and their combinations.

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FOSTERING COLLABORATIVE INNOVATION - HIGHER EDUCATION INSTITUTIONS AS INTERPRETERS IN TECHNOLOGY TRANSFER

by

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2015 University-Industry Interaction Conference Academic Proceedings: Challenges and Solutions for Fostering Entrepreneurial Universities and Collaborative Innovation

Fostering Collaborative Innovation - Higher Education Institutions as Interpreters in Technology Transfer

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Abstract

In this paper a technology knowledge transfer process between three higher education institutions and 16 enterprises is described, modelled and evaluated. In this research done from 2011 to 2014 three higher education institutions (HEI) collaborated in searching and interpreting latest technology knowledge data and transferring it to the enterprises. Each HEI had its main field of expertise and the research was done in technology teams consisting of experts from every HEI. The teams exploited their existing national and international networks and created new contacts to international universities, research centres and their enterprise networks.

All the subjects for the technology knowledge transfer came from the need recognition made in the enterprises. Small and medium sized enterprises (SME) were the target group because of their known lack of resources in technology knowledge acquisition. The absorptive capacity of the enterprises and the disseminative capacity of the HEIs had a significant role in the process. Knowledge transfer subjects were: automation, bioenergy and food processing technology.

Knowledge search proceeded in two phases. In first phase, research was wide-ranging. Focus was in new innovations, technological changes and standard changes. In first phase the research consisted of 14 technology case studies. In addition to these 14 cases also 11 subcases with specific knowledge needs were implemented in the second phase. In both phases the knowledge search consisted of many interlocked actions. Different kind of demonstrations and pilots in the cases were found to be very efficient methods in illustrating the benefits and challenges of the technologies.

Focused dialog between experts and enterprise representatives was the base for productive knowledge transfer. That way the potential information channels and knowledge transfer methods were tested. All the knowledge search, interpretation and transfer were made according to the regularly updated knowledge search plan. The design science research was an effective paradigm to define and structure both the technology knowledge transfer process and cases in technology transfer. The teams tested many different dissemination methods according to the absorptive capacity of the enterprises so that different kind of learners could assimilate useful knowledge.

In this paper the process is modelled based on the best practices detected in this research. The main outcome of this paper is the innovation oriented model for technology knowledge transfer in HEI-SME collaboration with a view to foster collaborative innovation. The model is evaluated from the HEIs’ and from the enterprises’ point of view. This new model emphasizes the importance of need recognition, continuous dialog and targeted open innovation process as well as the importance of the impact for the enterprises. The model is intended especially for collaboration of HEIs and SMEs.

Keywords

Technology knowledge transfer, collaborative innovation, higher education institution, small and medium sized enterprise, demonstration, model.

1 Introduction

The traditional, linear technology transfer between enterprises and higher education institutes (HEIs) has become to the end of its way. Today the collaboration between universities and enterprises is much more diversified, open innovation targeting and based on clear needs. The universities must create their own, regional technology knowledge transfer models with more impact in order to foster collaborative innovations. The main goal of this paper is to develop functioning ways of technology knowledge transfer between HEIs and SMEs, to identify the best practices and to model them.

This research is conducted as a technology knowledge transfer process between three higher education institutions and 16 enterprises with 25 cases. This paper presents the research project, the created transfer model as well as the evaluation and the conclusions of all these. Chapter 2 introduces the research framework and methods. In Chapter 3 the collaboration between HEIs and SMEs is explained. In Chapter 4 the created transfer model is introduced. In chapter 5 the created model is evaluated based on design science research principles and innovation attributes. Chapter 6 concludes the results and presents also the future research interests and the limitations of the created model.

2 Research framework and methodology

Earlier technology transfer was based on linear models. Created and transferred technologies were based on research results of universities. Technologies were protected and commercialised. Harmon et al. (1997) listed five types of technology transfer processes based on where the transferred technology was initiated, if the target enterprise of the technology transfer was an existing one or formed for that purpose, and based on the nature of the relation between the source and target of the transfer. These types are:

(1) technology is created at the university and transferred to an existing enterprise

(2) technology is created at the university and transferred to an existing enterprise that is created for that purpose

(3) technology is created at the university and sold to a venture capital enterprise

(4) technology is created at the university and a new enterprise is created to sell it

(5) technology is developed by the enterprise, but it needs help on specific fields of expertise from the university to utilise the technology.

Then in 2007, Perkmann and Walsh concluded that traditional technology transfer between universities and enterprises has focused mainly on IP rights, patents, licensing and commercialization of the research results whereas the modern technology knowledge transfer means much wider actions with different operation channels and mechanisms. These channels and mechanisms are used to describe cognitive and social paths of knowledge, information and other resources' dissemination and further development in collaboration between enterprises and HEIs. (Perkmann and Walsh 2007)

Nowadays there is need for technology transfer models that are nonlinear, regionally engaged and based on interaction and knowledge sharing between actors. The universities must change their technology transfer models from only push type to both push and pull type models.

Technology transfer has come to its turning point in the 2020th century. Bradley et al. bring out insufficiencies of traditional, linear technology transfer. They also point to increasing importance of technology transfer for economic development and innovation. Universities must create their own technology transfer models to support and boost their research activities in order to better exploit them with the enterprises. (Bradley et al. 2013)

Buganza et al. (2014) conclude that the relationships between SMEs and universities vary across the different phases. There are two main phenomena that explain why some enterprises are more able than others to engage in complex collaborations with universities and research centers. The first phenomenon relates to step-by-step development, trust, partner familiarity and technological familiarity. The enterprises that are able to push the collaboration till the research phase follow a progressive collaboration model. This increases the likelihood of a successful collaboration. The second phenomenon relates to technology management and project management capabilities of the enterprises. These capabilities allow them to reduce the cost and risk associated with defining their needs correctly, assessing the results and increasing the chances of a successful collaboration. (Leino and Laine 2014, Buganza et al. 2014)

Laine et al. reported, piloted and tested a multidimensional process model for technology knowledge transfer. The first process model was used in scanning, searching and interpreting international technology knowledge for SMEs. The technology knowledge transfer process model was created by testing and piloting different phases and steps. This first model was based on five steps:

- Need recognition
- Knowledge search plan
- First knowledge search cycle
- Detailed knowledge search
- Evaluation

The technology transfer processes were executed according to the model in 2009-2011. After every step the detailed phases of the step were documented and the best practises were detected. (Laine et al. 2015)

According to the experiences of testing and piloting the first model of technology transfer and collecting the best practices detected during the pilot the next phase of the technology transfer model developing was taken. The technology transfer model was decided to be developed in cooperation with two other universities. With this cooperation the developing of the model could be possible to do with a larger research group and with a wider sample group. At the same time the created technology transfer philosophy could be disseminated to other universities of applied sciences. These identified developing and dissemination goals led into the research project called Universities of Applied Sciences as interpreters of international technology knowledge transfer for SMEs.

In this research SMEs were chosen as target organisations because especially SMEs do not usually have enough resources or background knowledge to search and utilise newest technology information. As one solution for this, the university experts can have multi-field, versatile expertise and at the same time they have the technology, research and pedagogy competences to filter and interpret the technology knowledge in ways that the SME representatives may utilise in their work. In other words university experts' disseminative capacity is widely exploited. Altogether 16 technology enterprises were chosen to participate this research and development project.

2.1 Goals for the technology transfer development

In this research a wide-ranging group of experts coming from three universities worked together in technology transfer by searching, filtering and interpreting the newest technology information. One of the goals of this research was to model and test the possibilities of this kind of a cooperation. By developing technology transfer from three universities' point of view the functionality and general usability could be confirmed. This ensures that after the developing phase the technology transfer process model may be embedded as everyday activity of these universities and may also be adapted and applied in other universities.

The goals set for this research may be divided into the goals that should be achieved during the research project and into the goals achieved by the research results after the project. On long time period a technology transfer process model that improves technology knowledge of the universities and SMEs accelerates their operational preconditions. At the same time the SMEs learn how to exploit local universities of applied sciences in information search. While the university experts work as technology searchers, filters and interpreters for the SMEs they also strengthen their own knowledge. This leads to even better university education and ensures up-to-date professional skills of the graduating students. Technology transfer strengthens the dialog between university experts and SMEs in order to find new ways to cooperate. A wide research project focusing on international technology transfer serves also the internationalization of the universities, combining it with the regional influence efforts and that way with the internationalization ambitions of the SMEs.

The goals set to be achieved during the research project were:

(1) To develop a technology transfer model suitable especially for the universities of applied sciences and embedding it to the universities participating this research project.

(2) To increase knowledge competences of the universities and SMEs and that way to develop the searching and controlling of international technology knowledge.

(3) To create such a multiregional model for wide-ranging university experts' cooperation that enables finding and interpreting as comprehensive technology answers as possible to the SMEs' needs.

In this research the case studies were used to best practise identification. The cross sectional study based on 25 case studies was used to develop the technology transfer model suitable especially for SMEs and for the universities of applied sciences (UAS).

2.2 Absorptive capacity

A widely discussed subject by scholars is enterprises' ability to exploit and use new knowledge. Enterprises need a certain level of internal resources or absorptive capacity to be able to access certain external knowledge. Absorptive capacity is seen as a threshold factor in the effectiveness of university-industry interaction.

Two factors affect an enterprise's incentives to learning and ability to apply new knowledge, quantity of knowledge and difficulty (cost) of learning (Cohen et al. 1990, Nieto et al. 2005). Absorptive capacity is the ability of an enterprise to recognize the value of new, external information, assimilate it, and apply it to commercial ends (Cohen et al. 1990). Learning is determined by the characteristics of the knowledge. Level of complexity and suitability to enterprise's absorptive capacity are important. There exists a significant positive relationship between absorptive capacity and innovative effort of an enterprise (Nieto et al. 2005).

Disseminative capacity is the counterpart of absorptive capacity and it is a competence of the knowledge source. Kuiken et al. (2011) define dissemination capacity as the capacity of an organization or institute to transform its knowledge into value for other actors in its network with a commercial and/or learning purpose. The key components of the definition of Kuiken et al. (2011) are the purpose on knowledge transfer, the transformation of knowledge, the importance of valuable knowledge from a respectable source and issues of network and inter-organizational dynamics.

Efficient knowledge sharing is not only dependent on the recipients' absorptive capacity (Cohen et al. 1990) but demands a collaborative effort, implying that it depends also very much on the knowledge sender's attitude and behavior. Sharing of knowledge depends on the ability of the source to communicate his/her knowledge in a way the receiver can understand (Minbaeva et al. 2004). Szulanski (1996) argues that disseminative capacity is dependent on both the ability and willingness of knowledge senders to share knowledge. Disseminative capacity can be formulated also as question, how well university understands the needs of enterprises.

2.3 Design science research

Design science research is a research method based on problem solving paradigm. Design science research processes focus on innovative results that raise from design and construction creativity of humans and have clearly recognized needs. Design science research also tries to identify the creativity of designers and engineers and to focus it in application development. (Hevner and Chatterjee 2010)

March and Smith (1995) deal with design science research via research activities and research outputs. The artifacts of the process, like constructs, models, methods, and pragmatic instantiations, are seen as the research outputs. It can be stated that in engineering sciences the artificial phenomena take much larger role than the natural phenomena. Combining artificial phenomena with human creativity leads to artifacts designed to meet the needs of the subject. The research activities like build, evaluate, theorize, and justify, are seen as the other dimension in March's and Smith's paper. The artifacts like systems, devices and applications are built and evaluated as goal-orientedly as possible. At the same time these artifacts are theorized and the theories are justified. (March et al. 1995)

Hevner et al. (2004) state that in design science research the novel knowledge and understanding come from the design process of an artifact. They determine very clear guidelines for design science research process:

(1) Design as an artifact

(2) Problem relevance

(3) Design evaluation

(4) Research contributions

(5) Research rigor

(6) Design as a search process

(7) Communication of research

First of all, the whole design science research process rests on an idea of an artifact that should be designed. Next, it is very important to make sure and indicate that the problem is relevant. The problem relevance should be defined for example by comparing the present state and the future state of the artifact and then by defining the relevance of the change between these states (Hevner et al. 2004).

The evaluation phase of the design is based on analysis of the artifact's usefulness, quality or/and effectiveness. The evaluation methods may be observational, analytical, experimental or descriptive. In design science research there must always be a clear result like new artifact, new knowledge and/or novel method. Research rigor refer to the rigorous construction and evaluation methods used in the research work. Choosing the appropriate techniques to design and methods to test and evaluate the artifact is crucial (Hevner and Chatterjee 2010).

Eventually the whole design process is a knowledge search process where useful and available methods are used to find requisite information needed to accomplish as practical solution as possible. After the design process it is essential to introduce all the significant knowledge of the design work to both technology-oriented and management-oriented groups of interest (Hevner et al. 2004).

3 Research implementation

Technology knowledge transfer research project was implemented through case studies where SMEs could exploit the research knowledge and international connections of the universities. In order to achieve as meaningful learning outcomes as possible, all the SMEs participating this research were interviewed by the university experts. In the interviews the core technology knowledge needs of the enterprises were recognized. By combining recognized needs the main topics for the case studies were identified. This kind of need recognition follows the procedures of design science research.

Case studies consisted of both general knowledge needs and specific questions of certain technology application possibilities. The research plan was put together on the strength of the interviews, identified cases and known international technology knowledge sources. The identified main topics for the case studies were automation, bioenergy and food processing technology.

First there were 14 case studies in this research. The subjects of case studies were combinations of similar knowledge needs recognized in several enterprises. During the specific knowledge search some of the case studies were divided into separate subcases so that in total this research consisted of 25 cases and subcases. Subcases under each case were based on the same technology but they demanded different kind of specific knowledge.

3.1 Iterative actions

In this research the knowledge search was executed iteratively in two phases. The first phase was wide-ranging with the focus on new innovations, technological changes, standard changes and in suitable events, seminars and conferences. Then the focus of the second phase was in deeper and more precise cases which were sifted from subjects of the first phase. Both phases contained many actions performed interlocked. Especially in the second phase the modus operandi was iterative as the specific knowledge search was executed in cycles. After every search cycle there was a knowledge transfer point where the enterprise representatives could assimilate the information and identify more precise knowledge needs.

The knowledge search was done in teams consisting of experts from participating universities. The teams exploited their existing national and international networks and build new contacts to international universities, research centres and their company networks.

Continuing and focused dialog between experts and enterprise representatives was the base for productive knowledge search. That way the potential information channels and knowledge transfer methods were tested. The plan for knowledge search was updated regularly according to the hopes and needs coming from the enterprises. When in one case the experts only had to update their expertise, in other case they had to do deeper and wider research to assimilate new knowledge. At the same time their expertise accumulated significantly. The action plan for this research project is shown in figure 1.

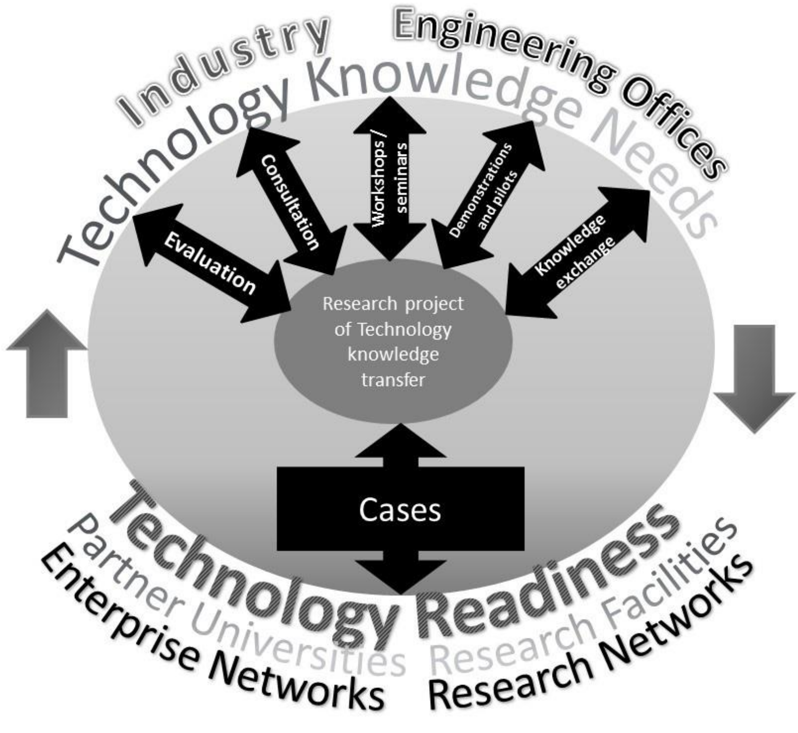

Figure 1: Action plan for the research project of technology knowledge transfer

3.2 Knowledge search

The technology knowledge search was conducted through knowledge search visits, literature reviews and expert interviews. Different kind of fairs and seminars were good destinations for knowledge search of applied research while international conferences, international partner universities and their research institution partners worked as easily approachable sources of the newest technology knowledge.

In this research the knowledge search visits were made to diverse and moderately goal-oriented destinations. The knowledge search on these visits was focused on wide-ranging trends and maturity of the technologies but at the same time some specific answers were also searched for detailed needs of the enterprises. Especially fairs were discovered to be were effective knowledge sources especially when the knowledge needs and specific questions were clearly defined beforehand. The fairs showed very graphically different research results that may be applied to the processes or products of the enterprises attending this research project.

The conferences are sources of more scientific research results which usually take more time to be applied in SMEs. At the same time the conferences were found to be good places to network and find new international partners.

Literature reviews were used to study newest technology research results and for example patent applications. The most useful articles were found to be those with examples of applying the technologies in real environments with tangible subjects. These articles showed quickly how the technology could be exploited and what are the challenges of applying it. Also different device suppliers are publishing more and more articles about their devices, solutions and piloting them. Although these articles give specific information of the device functions they are always also marketing materials, which should be considered critically.

The expert interviews in this research were made with known experts, partners and device suppliers. These interviews were found to be very informative especially in the early days of the study. The starting point for the study and the technology ability of the moment were easy to sketch with the expert interviews. They were also very helpful when finding answers to questions emerging from articles, seminars and fairs. Expert interviews gave always some tacit knowledge too.

3.3 Knowledge transfer

At the beginning of this research the potential knowledge dissemination methods were listed:

- written reports
- workshops
- webinars
- enterprise specific knowledge transfer meetings and expert’s reports
- technology demonstrations
- figures and videos with commentary
- expert floors
- case descriptions
- events in the enterprises
- technology application pilots

During the knowledge search actions it became clear that all the written material should have its own platform where all the participants may study and utilize it. For this purpose a knowledge sharing platform was created to university's virtual learning environment. The knowledge sharing platform opened to the enterprises also possibilities to study subjects, cases and materials which they did not name as their core technology knowledge needs.

One of the key knowledge dissemination methods in this research project was demonstrating. General demonstrations of certain technologies were generated to universities' laboratories. With these demonstrations the basic features, the requirements and the potentiality of the technologies were illustrated. Some specific demonstrations were generated according to the hopes of the enterprises. They were used to demonstrate how the technology could be applied to solve certain problem. The demonstrations were presented in seminars and workshops but also in enterprise specific meetings. The participants gave very positive feedback about the demonstrations. The demonstrations are a good way to concretise the potentiality of the technologies but they also highlight the challenges of using the technology and exclude the unsuitable solutions.

The expert's reports written according to the demonstrations give the enterprises tangible knowledge for their specific needs. The reports are used as guidance in decision making of investments and developments.

The seminars and workshops were organized around certain technologies. The universities' experts and device suppliers' representatives presented different kind of technologies, applications and demonstration in these events. The most demanding challenge in organizing seminars and workshops is to get reasonable amount of participants. When the distance from the workplace to the seminar place is significant, like over an hour per way, the seminar may take all of the working day and it is surely too long for an SME participant. It is important to convince these participants that it is useful for them to participate. The seminar and workshops got also very good feedback, mostly because of the application examples and demonstrations.

3.4 Case example: 3D imaging for measuring geometrical characteristics of reinforcing bar

As a case example of this research project a technology knowledge transfer process and an innovation path of 3D imaging for measuring geometrical characteristics of reinforcing bar is described in this chapter. This case started with several enterprises which needed to get familiar with possibilities to use 3D imaging technologies in quality control of their products. The university machine vision experts used their existing knowledge and enhanced it in order to develop illustrative demonstrations of using 3D imaging in quality control. According to these demonstrations one enterprise hoped to have a more specific example of using 3D imaging in quality control of their product, reinforcing bar (re-bar) and in speeding up the measurement process.

This started the second phase where the specific 3D imaging technologies were studied and tested in order to find a suitable solution for measuring the re-bars. None of the known 3D imaging techniques did not give the 3D model as accurate as needed. The whole specific knowledge search with a pilot system as a set goal was a design science research process which aimed to an innovative 3D imaging system for measuring geometrical characteristics of re-bars.

The designing of the re-bar 3D imaging system is based on testing the different imaging and lighting methods. These tests showed that imaging technique based on silhouette imaging is the best way to perform measurements that would achieve requirements set by the standard. This innovative imaging system is based on a combination of 10 Mpix machine vision camera, telecentric optics, backlight and a stepping motor which rotates the re-bar rod. The camera images the re-bar from 400 different directions and the computer software made for this purpose analyzes them. The software processes the images and creates an accurate 3D-model as a result from which every geometrical characteristic can be measured. The measurement system was evaluated by using it parallel with the former measurement system (caliper). At the same time the evaluation was also made by comparing the results to measuring results from a certified measurer. The 3D imaging system for measuring geometrical characteristics of reinforcing bar is now in use and will be developed further based on user experiences. (Valo et al. 2013.)

4 Innovation oriented model for technology transfer

Based on the case studies in this research project the best practises were identified. The cross sectional study of all the case studies and best practices led to the development of the Innovation oriented model for technology knowledge transfer in HEI-SME collaboration (Figure 2).

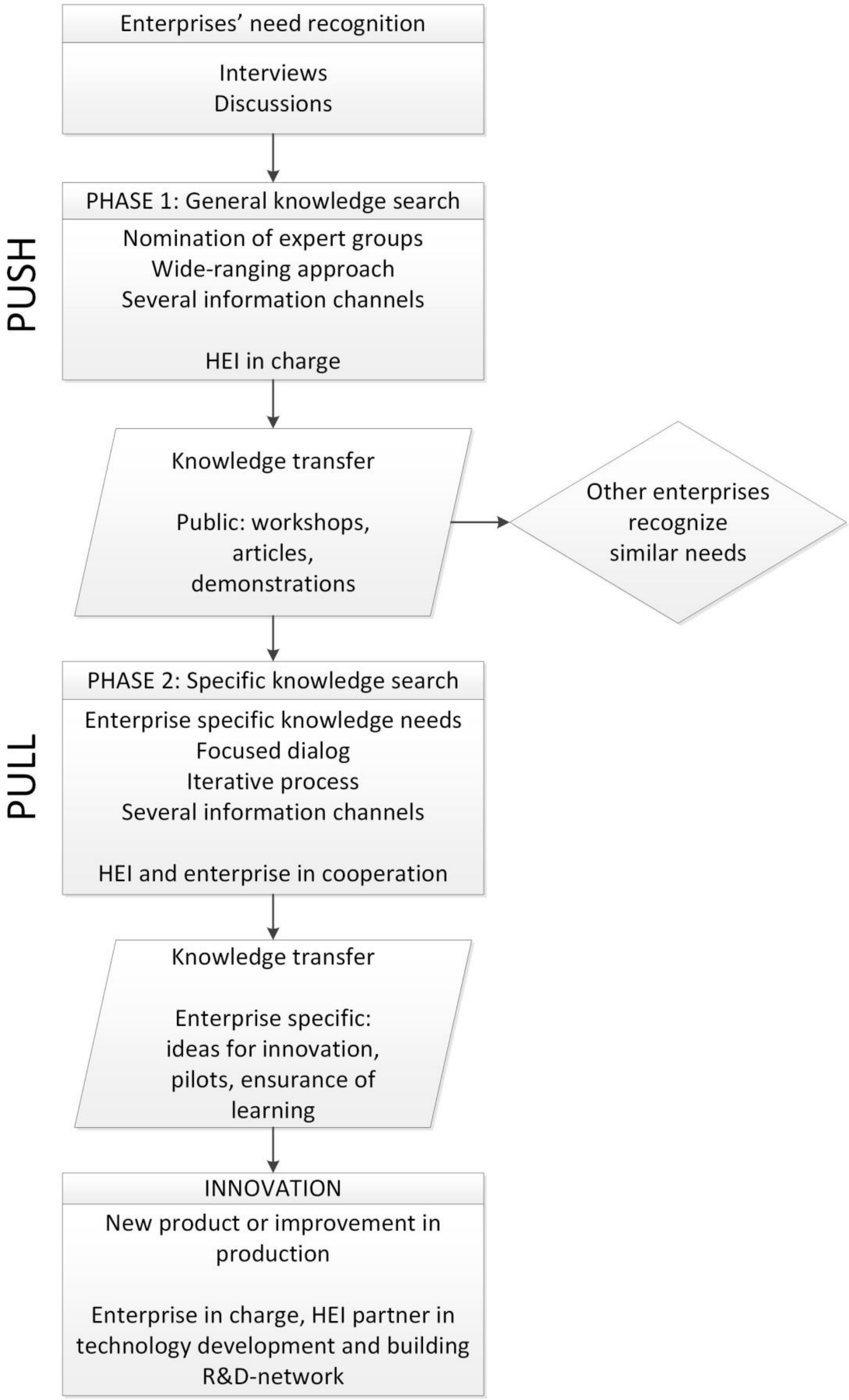

Figure 2: Innovation oriented model for technology knowledge transfer in HEI-SME collaboration

The key element of successful HEI-SME -cooperation is to understand the business environment of SMEs from their perspective. SMEs have limited resources for development and they usually do not have own R&D -department – often not even one person whose main job R&D would be. Generally SMEs know already a potential end customer at the beginning of the development work. SMEs rely largely on device vendors as problem solvers. There are, however, situations where the enterprises try to expand their knowledge and recognize that external support is needed to acquire the necessary knowledge and know-how. HEI is an independent source of information and knowledge. This forms the basis for HEI-SME collaboration.

When the discussion on technology knowledge transfer cooperation starts, the SME has a vision of the knowledge it is looking for with the support of the HEI. The enterprise is interested in finding a solution to their problem, but the challenge for the HEI is to identify the real problem. The recognition of the relevant problem and actual need for knowledge in the SME is essential that the HEI can nominate right experts (Figure 2) for the knowledge search in order to ensure a successful output. The experts can came from several HEIs. The technology knowledge transfer process starts with the first discussion (Figure 2).

The end result of the need recognition process is a project plan and cooperation agreement. It is essential to have the appropriate expertise and decision-making ability from both parties (HEI and SME) at the discussion table. The HEI shall be able to have the flexibility to promote enterprise development projects without unnecessary bureaucracy.

The future business potential of the enterprise should be the point of view in the need recognition process. Continuous partnership should be the target rather than the one-time projects. New needs will be often recognized during the ongoing knowledge transfer project. In many cases the collaboration will continue with new or related subjects later.

It is important to use several information channels (Figure 2) because the technology knowledge needs of enterprises are so various. The HEI should make strategic choices on the technology areas in which it would actually produce new knowledge and new information itself and on the areas in which it actively monitors. The strength of the universities of applied sciences is that they are mostly multidisciplinary institutions. New innovations in SMEs are often generated using technologies that have been applied in some other industries. Important sources of technology knowledge are also other companies. In particular, small and medium-sized businesses, who have limited resources and the pressure to success in each technology transfer project, favor already tried and tested technologies by applying them in their product and production innovations. In an SME a new technology does not often mean a really new radical technology but a new kind of application. The skill to acquire the necessary knowledge in a variety of different sources and use it to fulfill the knowledge needs of the partner enterprise are essential skills of the experts of a HEI.

HEI’s experts have the responsibility to choose the channels used in phase 1 knowledge search to ensure that it is wide-ranging to meet the case. For this reason it is named PUSH-type action in the developed model (figure 2). In the beginning of the knowledge transfer project also the technology transfer practices used during the process must be agreed. Who will keep touch to whom and with what intensity as well as how the project will be reported? All decision making which directs the further steps of the knowledge transfer project needs to take place in the enterprise. The technology data of phase 1 (figure 2) will be transferred simultaneously directly to the customer SME as well as disseminated outside to other enterprises. In phase 2 the knowledge search is enterprise specific and the technology data is transferred to the customer only. It is named PULL-type action in the developed model (figure 2) because the search and the dissemination is done specifically as answers to the questions and needs of the enterprise.

The most considerable things in choosing the knowledge dissemination practices are the expectations of the enterprises, the success of the previous experiences as well as the disseminative capacity of the HEI together with the pedagogic skills and interests of the experts. As educational institutions the universities of applied sciences have the advantage that the experts have pedagogic skills and experience of often a variety of dissemination methods. It is important, however, to discuss with the enterprises at various stages of the project what dissemination methods would help them to use the information effectively. Lack of implementation can ruin the whole end result.

HEIs which do not belong in the top level producers of new knowledge can do much exploitable applied research to the industry. The ability to apply technology to the needs of your business will determine the outcome. The technology knowledge transfer process is complex, iterative, multi-directional and depends heavily on the parties' existing knowledge, beliefs and experiences. The performance should be measured from the enterprise's point of view.

The time horizon of the various technology knowledge transfer projects can differ from the immediate launch of a new product to years of decisive strategic knowledge construction. The key question in technology knowledge transfer process is how to ensure the enterprise's ability to effectively use the new technologies and to take advantage of it; it is at the same time question about the enterprise's absorptive capacity and HEI's disseminative capacity. The SME's own commitment and participation are thus the key elements to a successful outcome. HEI shall use suitable dissemination methods and channels to ensure that the enterprise understands the results and will be able to exploit the new knowledge. Their adoption and usage of the new knowledge will remain the responsibility of the enterprise. Because the enterprise has decided to acquire knowledge from outside it is likely that its staff do not have corresponding knowledge as the HEI's experts. Direct communication between people has an essential role in successful knowledge transfer process. Only rarely a mere written report is enough even that is also important.

5 Evaluation of the model

In this Innovation oriented model for technology knowledge transfer in HEI-SME collaboration (figure 2) the technology transfer research process is clearly non-linear. The subjects for the research and technology knowledge search are based on strictly identified needs and are coming straightly from the enterprises. Both the technology knowledge search and the research based on the search results are iterative and have many evaluation points.

Demonstrating and piloting are essential dissemination methods in the technology transfer process. When the need and the purpose of a demonstration or a pilot is identified the research activities of a design science research process may be implemented. Implementation gives the creative humans possibilities to design new innovative demonstrations and pilots to make the advantages of a certain technology as apparent as possible. The design science research is found to be very effective paradigm to define and structure both the technology knowledge transfer process and cases in technology transfer.

The innovation oriented model for technology knowledge transfer in HEI-SME collaboration introduced in this paper, is a new approach for need- and dialogue-based technology knowledge transfer. This model:

(1) is focused especially on small and medium sized enterprises (SMEs).

(2) is non-linear with need recognition and many iterative cycles.

(3) is not just about searching and disseminating knowledge passively but also

  (a) combining existent knowledge with new searched knowledge.

  (b) demonstrating the possibilities of the technologies based on searched and interpreted technology knowledge.

  (c) piloting the technologies in real cases of the enterprises.

  (d) transferring the knowledge interactively and iteratively in order to find answers and new innovations.

(4) deepens the collaboration between the HEIs and the SMEs while the model actions proceed and

  (a) increases the responsibility of the enterprises.

  (b) supports push to pull transformation of the technology knowledge transfer.

(5) takes the absorptive capacity of the enterprise into account

  (a) by demonstrating and piloting the technologies based on the needs and on the absorptive capacity of the enterprise.

  (b) by transferring the technologically interpreted and analyzed knowledge by the experts with dissemination skills.

Absorptive capacity theory and design science research method impacted highly into this research. They affected not only to the selection and designing of the cases, but also to the modelling of the technology knowledge transfer process. The strength of the modelling was in adequate amount of cases which were also evaluated. With case evaluation the best practices were detected.

First of all, the cases were based on an idea of an artifact that should be designed. In discussions between experts and enterprises it was made sure and indicated that the problem was relevant. The problem relevance was defined by comparing the present state and the future state of the artifact, impact of the artifact and its utilization, and then by defining the relevance of the change between current and future states like Hevner et al. (2004) stated.

The evaluation phase of case design was based on analysis of the artifact's usefulness, quality or/and effectiveness. The evaluation methods were observational, analytical, and experimental. In all cases there was a must to be a clear result like new artifact, new knowledge and/or novel method. Choosing the appropriate techniques to design and methods to test and evaluate the artifact was crucial, like noticed by Hevner and Chatterjee (2010).

Eventually the whole design process of a case was a knowledge search process where useful and available methods were used to find requisite information needed to accomplish as practical solution as possible. After the design process it was essential to introduce all the significant knowledge of the design work to both technology-oriented and management-oriented groups of interest. This demanded both absorptive capacity of the SMEs and appropriate disseminative capacity of the HEIs. This supported findings of Hevner et al. (2004).

The cross sectional study based on 25 case studies was used to develop the technology transfer model suitable especially for SMEs and UASs. 25 case studies was a sufficient amount in order to make generalizations to the model.

Rogers (1995) listed five attributes that many widely adopted innovations have: it adds value for the user of the innovation, it is compatible with the values and needs of the user, it is simple to understand, it can be tested without total commitment to it, and the results of using the innovation are visible for the user and observers as well. The innovation oriented model for technology knowledge transfer in HEI-SME collaboration introduced in this paper adds value for SMEs involved by accumulating the knowledge base of the enterprise. Because the model is nonlinear and based on interaction and new combinations of knowledge the SMEs can find even something they did not know they were looking for. New networks can add value also in the future. So, it is not only what has been created so far but also building potential and capacity for the future. Compatibility with values is not as clear, despite that solving SMEs problems and aiming to new innovations is very attractive way to tempt SMEs to participate into the process. Although the process may look complex and the subjects can be very complex, the process is simple with two cycles and interaction. A lot of the complexity is handled by the HEIs. However, level of commitment in the target SMEs must be raised during the process. Triability is based on discussions in the beginning of the process and on the two cycles. If the SME is not willing to continue at some point of the process, it can withdraw from the process. Visibility of the results is seen in SME when it uses the knowledge in a new product, service or process development. Results are visible for larger public via publications, seminars, etc. and also when new products or services are released. Process innovations are seldom published. All together it can be seen from above that the created technology transfer model has properties that Rogers listed to be properties diffused innovations typically have.

One part of the model worth mentioning in this evaluation chapter are the technology demonstrations and pilots. They were found to give illustrative information and also to show the challenges of applying the technology. The SME participants gave very positive feedback about the demonstrations and the pilots.

6 Conclusions and recommendations

This research project of developing the innovation oriented model for technology knowledge transfer in HEI-SME collaboration was influenced by design science research. The model was created by studying existing action models, experimenting selected models as well as evaluating realized actions and identified best practises used in the technology knowledge transfer cases. The model is not just researching or just researching and creating innovations but also evaluating the research results and innovations. Therefore, according to this also the technology knowledge transfer actions based on the model follow the design science research methodology. Success of the case studies on the first knowledge transfer cycle could easily be detected on ground of large group of subcases risen from the case studies.

There are some limitations for the study. The model is created for collaboration between SMEs and HEIs, especially UASs and their networks. It may not be generalisable to other fields of collaboration. There may be differences between SMEs. Like, some enterprises may be more entrepreneurial and have more positive and pragmatic approach towards new product, service and process development. The model fits for these SMEs. The model was created and tested with traditional fields of industry. This research takes no stand on collaboration with startups for example. The model is always a simplification of real world. Therefore it must be applied in context.

The future research interests on this field cover testing with startups and other modern fields of industry. The model should also be piloted on the other fields of operation like on the field of well-being enhancing technologies or on more service-oriented areas of business.

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VI

TECHNOLOGY RESEARCH AND INNOVATION IN ENGINEERING EDUCATORS' PROFESSIONAL DEVELOPMENT

by

Leino, Mirka

Submitted to European Journal of Engineering Education 2017

VII

MACHINE VISION IN SMART HEALTH AND SOCIAL CARE

by

Leino, Mirka & Valo, Pauli

In Book Merilampi, S., Sirkka, S. and Iniewski, I. (ed.) Introduction to Smart eHealth and eCare Technologies 2017, 129-148

7 Machine Vision in Smart Health and Social Care

Mirka Leino and Pauli Valo

CONTENTS

7.1 INTRODUCTION

The development of machine vision technologies has been remarkable in the past 10 years. The applications, and therefore, the research, have mostly been intended for industrial use. Today, the costs and usability of the machine vision equipment have improved, making machine vision applications much easier to employ in everyday use. There are significant advantages in machine vision compared with traditional methods of diagnostics or physical therapy. First, machine vision is a non invasive technology. For instance, there is no need for needles in imaging. It is possible to image wide areas simultaneously by machine vision. This makes the procedure quick and repeatable, even if there is no certainty where to image. Machine vision can be used to monitor health and well-being, for example, the physical and physiological changes in a human body. Because the applications have been designed for industry, new innovative adaptations are needed to make them applicable for enhancing well-being (Leino et al. 2015).

7.2 BASICS OF MACHINE VISION

This chapter describes the basics of machine vision in such a way that a nonautomation expert is able to understand the technology. The basics are summarized by taking into consideration the most important aspects for smart health and social care. The explanations are illustrated by figures and pictures.

Machine vision is often defined as a mechanical sense-imitating human vision. The following definition is a generally accepted definition for machine vision:

> The automatic acquisition of images by noncontact means and their analysis to obtain desired data for use in controlling a process or an activity (Automated Vision Inc. 2006).

Machine vision is an intelligent combination of digital cameras imaging the target, optics transmitting the light to the sensor, lighting systems illuminating the target, and software analyzing the image. Earlier machine vision equipment was mainly intended for manufacturing and other industrial applications, but today, it is spreading into smart health and social care applications, for example, medical applications, personal security applications, and activating and motivating (exercising) applications.

7.2.1 Traditional Machine Vision

A traditional machine vision system (Figure 7.1) consists of:

- Camera
- Optics
- Lighting
- Interface
- Computer
- Analyzing software

7.2.1.1 Choosing a Camera

The camera is the most important part of a machine vision system, and it should be chosen to always include the needed information of the target. Yet, when is the image good enough? First of all, the features of interest must be well defined and contrast must be high, with adequate number of details. Second, the images must

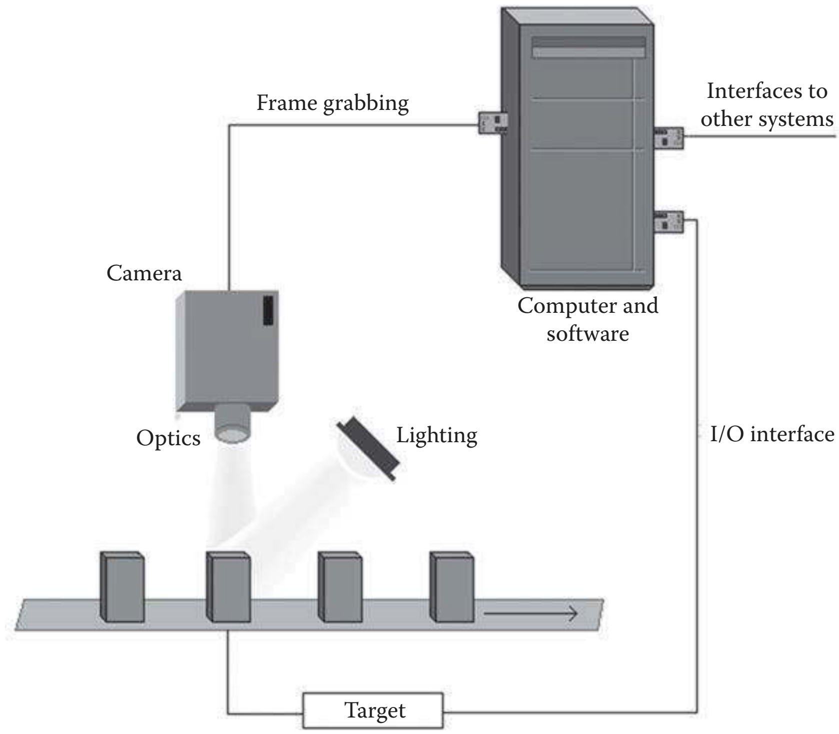


FIGURE 7.1 An overview of a machine vision system.

be repeatable and all the features in the image must also exist in the physical world. In other words, there should not be any noise or ghost images. Third, the possible changes in the environment should have minimal impact on the image.

When choosing the camera and optics for a traditional machine vision system, one should know the target surrounding and lighting. There are a large number of possible cameras, so the selection should be done based on the circumstances, for example, whether the targets are moving or still or how large the target parts are and how far they are.

The type of the camera is chosen when all the factors affecting the image quality have been taken into consideration. The selection depends on whether the system needs a camera with a matrix detector or with line-scan detector. The detector is the part of a camera that receives the light reflecting from the target and creates the image. If the detector is matrix shaped (Figure 7.2), the image will be two-dimensional, and if the detector is line shaped (Figure 7.3), the image will also be a line. A matrix detector is by far the most used detector type in machine vision. It is a good choice when imaging separate or immobile targets.

The line detector is good for imaging moving or continuous-flow-type targets. The line detector is used like a scanner to join the imaged lines together in the computer. The result looks like a continuous two-dimensional image. Figure 7.4 shows the difference between imaging with a matrix camera and with a line scan camera.

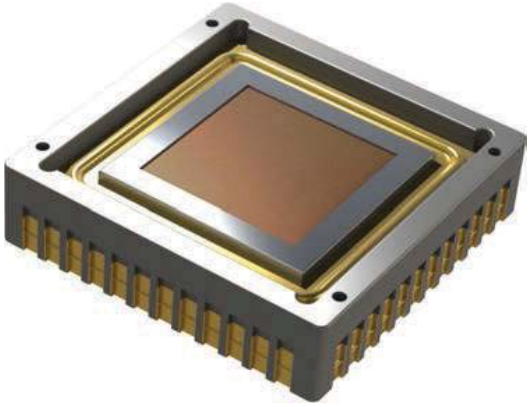


FIGURE 7.2 Matrix detector.

FIGURE 7.3 Line detector.

The next choice is done between color and monochrome cameras. According to the general rule, if you do not need to recognize colors, you should always choose a monochrome camera. Monochrome cameras are more accurate because of the estimations made in typical color imaging techniques. Especially if the machine vision system should measure anything, the camera type should be monochrome.

After choosing the camera type, resolution must be determined. Resolution refers to the amount of pixels in the image. In machine vision systems, resolution is expressed in pixels in width and height. There is usually no unambiguity in the determination of resolution. A principal rule is that there should be enough pixels but not too many. There should be enough pixels to see the target, but more the number of pixels, the longer it will take for analyzing, because more number of pixels means that there are more points to analyze. Unnecessary pixels also make the camera more expensive. Some general rules of thumb may be set for pixel resolution requirements. If the purpose of the system is to observe the presence or absence of an object, there should be at least three to four pixels in the object area. To read, for example, a data

FIGURE 7.4 Matrix camera (on the left) images in two dimensions and line camera (on the right) images one line at a time, and computer combines the lines as a continuous 2D image, as seen on the right.

matrix code, there should be 8–10 pixels per each data matrix cell. In identification of an object shape, there should be from hundreds to thousands of pixels, depending on the complexity of the object shape. In measuring, for example, some geometrical characteristics of an object, the pixel resolution should be 1/10 to 1/3 of the tolerance requirement; otherwise, there should be 3–10 pixels per tolerance value. For example, if the goal is to measure the height of an object with a tolerance requirement of 0.1 mm, there should be at least three pixels per millimeter.

7.2.1.2 Choosing the Optics

When the camera features have been determined, the appropriate optics are chosen. The four main constructs of choosing the optics are (1) focal length (f), (2) working distance, (3) field of view, and (4) detector size (Figure 7.5).

Focal length is a feature of the optics, which is calculated based on working distance, field of view, and detector size. The longer the focal length, the narrower the angle of view from which the camera images (Figure 7.6). There are many focal length calculators for machine vision purposes on the Internet.

Working distance means the distance from the target to the front edge of the camera optics. The field of view is the size of the image area at the focal point. For example, if the object can be seen in an area whose size is 1000 mm wide and 800 mm high and the aspect ratio of the camera is 4:3, the wideness is the critical direction and the field of view must be determined as 800 mm. The size of the object is meaningful only if the object is always seen in the same position. Otherwise, the

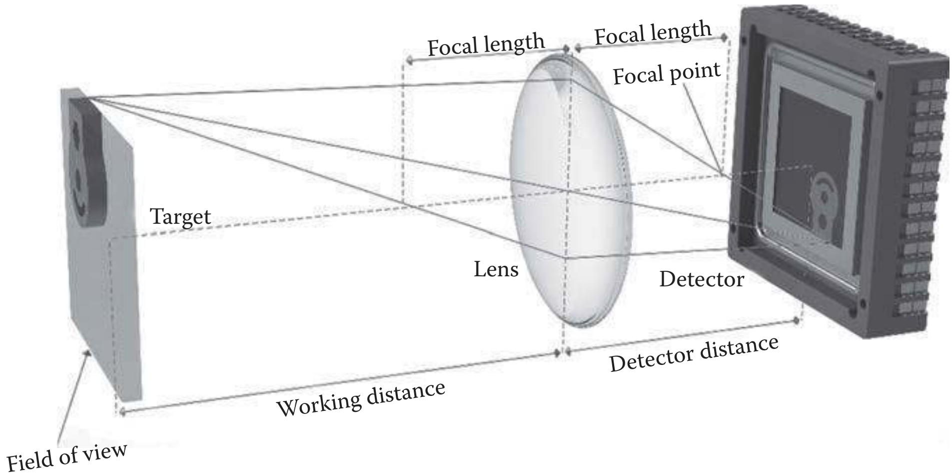


FIGURE 7.5 Significant features in choosing optics.

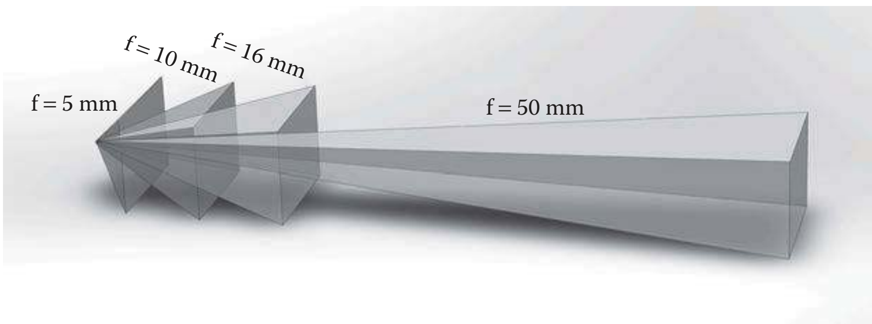


FIGURE 7.6 Comparison of different focal lengths and angles of view.

field of view must be determined as the whole area where the object could be positioned. The detector size is a feature of the camera; therefore, it must be taken into consideration when selecting the camera. The smaller the detector, the smaller the field of view with the same optics.

7.2.1.3 Choosing the Lighting

One of the most crucial phases of designing a machine vision system is choosing or actually designing correct lighting. Its importance cannot be exaggerated when the aim is to implement a stable and timely machine vision system. Good lighting design generates conditions for successful imaging, minimizes the need for image processing, and ensures that the features of interest are seen clearly in the image. If lighting has not been correctly designed, it could be impossible to implement even a simple system.

Lighting design always begins with analyzing the environment of use. When light and shadows, as well as their variations, are known, the next phase is to design and test the lighting of the system. This phase is based on target need recognition, lighting geometry, and technique testing; choosing the lighting source; filtering testing; and testing the interaction of the camera, target object, and lighting.

7.2.1.3.1 Lighting Geometry

When designing lighting, especially the lighting geometry must be considered. Almost any light sources can be used in machine vision. All of them have both good and bad features. The best result is detected by testing. Useful lighting sources are for example:

- LED (light-emitting diode)
- Halogen
- Fluorescent light
- Ultraviolet light
- Metal halide light
- Xenon light
- Infrared (IR) light

Lighting geometry is more important than the lighting source. Lighting geometry refers to the direction of lighting in relation to the target and camera. The most typical lighting geometries have been presented in the following subsections.

7.2.1.3.1.1 Bright Field Bright field lighting illuminates the target from roughly the same direction as the camera images. Bright field lighting is a good choice for general lighting, but it often causes problems in terms of so-called mirror reflections. When the light beam hits the target, the most powerful beam reflects directly to the camera. This results in bright, white areas in the image and prevents the analysis.

7.2.1.3.1.2 Dark Field Dark field lighting (Figure 7.7) brings the light to the target in a small angle in relation to the target surface. Dark field lighting is a good choice with flat, reflective surfaces, if bright field lighting causes mirror reflections.

FIGURE 7.7 Dark field ring light.

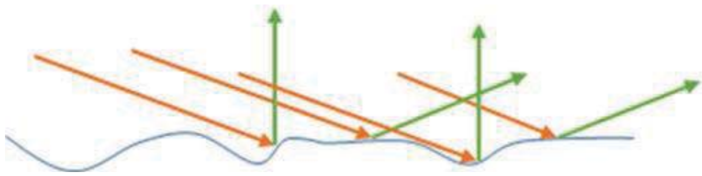


FIGURE 7.8 Light beams (orange) coming to the target and reflecting (green) from the target.

Dark field lighting is, in particular, used with flat surfaces, when the variations of surface quality should be visible. When the light beam hits the surface from the side, the light reflects to the other side from flat surfaces, while it reflects to the camera from holes, pits, and bulges (Figure 7.8). These surface changes are seen in the image as light areas; however, they are not any lighter on the surface. Respectively, the flat surfaces are detected as dark areas. This feature can be exploited, for example, in analyzing engravings or surface shapes.

7.2.1.3.1.3 Back Lighting Back lighting is a type of illumination where the subject is between the camera and the lighting source (Figure 7.9). Back lighting is usually used in order to cause the surface of the object reflect as little as possible. The camera sees the object as dark and the background as light. A dark object against a light background creates a perfect silhouette image, which is very suitable for recognizing the outlines of the object. Back lighting is often used in dimension measuring or in other outline inspection.

7.2.1.3.1.4 Diffuse Dome Lighting Diffuse light means light that comes from more than one point. Diffuse dome light (Figure 7.10) can be produced, for example,

FIGURE 7.9 Camera lighting setup with red back lighting and target object.

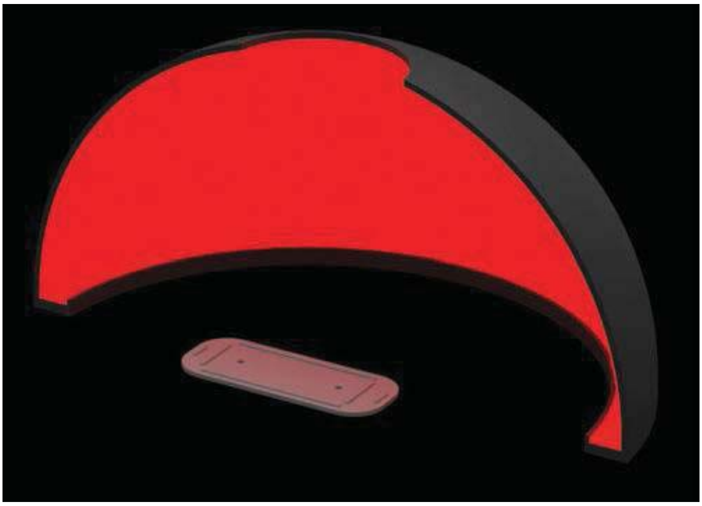


FIGURE 7.10 Cross-sectional drawing of a diffuse dome light.

by placing LEDs on an aluminum ring. The ring is attached to a dome, from whose inner surface, the light beams can reflect to different directions. This dome is placed above the target subject to make the light beams reflect from the inner surface to all possible directions. In this way, the image has no shadows or reflections, and the target is imaged with smooth and equal lighting. There must also be a hole on the upper surface of the dome, so that the camera can image through it. Diffuse dome should be used, for example, with shiny, convex, and concave subjects or with transparent packaging materials, with which other lighting techniques cause too bright reflections.

7.2.1.3.1.5 Axial Diffuse Lighting Axial diffuse lighting (Figure 7.11) is often implemented as an LED matrix, which creates a flat lighting surface. Light beams from this lighting surface are directed to a beam splitter, which directs them to the target object in 45°. In this way, all the light beams travel straight to the target object. The camera images above the axial diffuse light through the beam splitter, and the light beams reflect straight to the camera from flat surfaces, whereas from rough shapes, they reflect to the edges and not to the camera. The flat surfaces are detected as light in the image, whereas the rough shapes are seen as dark. It is an opposite of dark field lighting. In addition, axial diffuse lighting is used, for example, in engraving inspection.

7.2.1.4 Choosing the Analyzing Software

Basically, there are two types of analyzing software for machine vision in the market. The first type is a general-use software for computers. The software can be used with the products of several camera providers, and it usually comes with diverse features and extensive options. This type of software is mostly used with traditional PC-based machine vision systems. The other type of software is

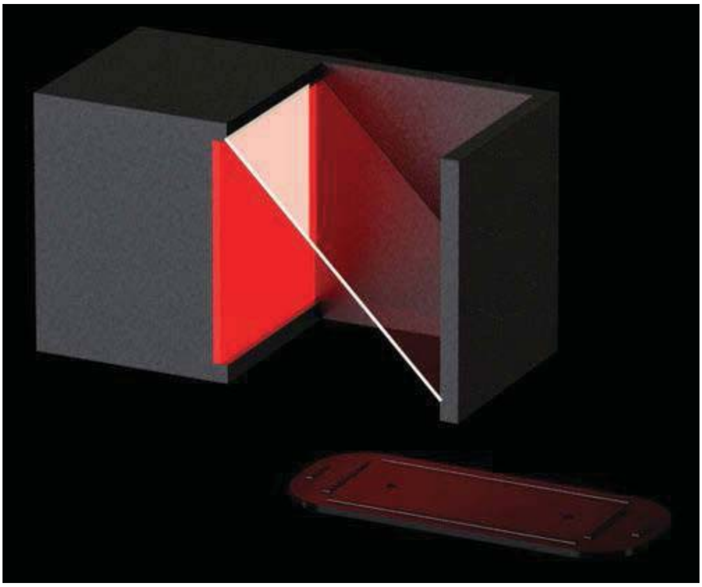


FIGURE 7.11 Cross-sectional drawing of an axial diffuse light.

camera-bound software, which can be used only with a certain type of camera. Analyzing software for smart cameras is usually this type of software. This type of analyzing software often comes with the camera, while general analyzing software usually costs from hundreds to thousands of Euros. In most cases, the analyzing software is chosen on the basis of the experience of the designer.

7.2.2 Smart Camera Systems

Smart camera is an independent camera unit with an integrated processor and memory. While a smart camera images the target and analyzes it without a computer, a traditional PC-based machine vision system uses a camera to image the target and then sends the image to the computer, which analyzes it. A good smart camera can be very quick, although it can never be as quick as a modern computer. However, a smart camera can solve simple problems very efficiently and reliably.

The increase in the use of smart cameras in machine vision has been exceptional. Although smart cameras provide a potential for easier use of machine vision and a more compact setup than the conventional PC-based machine vision, smart cameras also set some limits on the versatility and complexity of the applications. In smart health and social care, smart cameras provide invisible and easy-to-use technology to the applications. Smart cameras are very useful, for example, in inspecting if the patient is falling, if a person with impaired memory has left a coffee maker on, and if there are any security problems in the services for the aged or the disabled. There is rarely a need to send the image anywhere in smart camera applications. As a result, the privacy of the user is not compromised.

7.2.3 3D Imaging

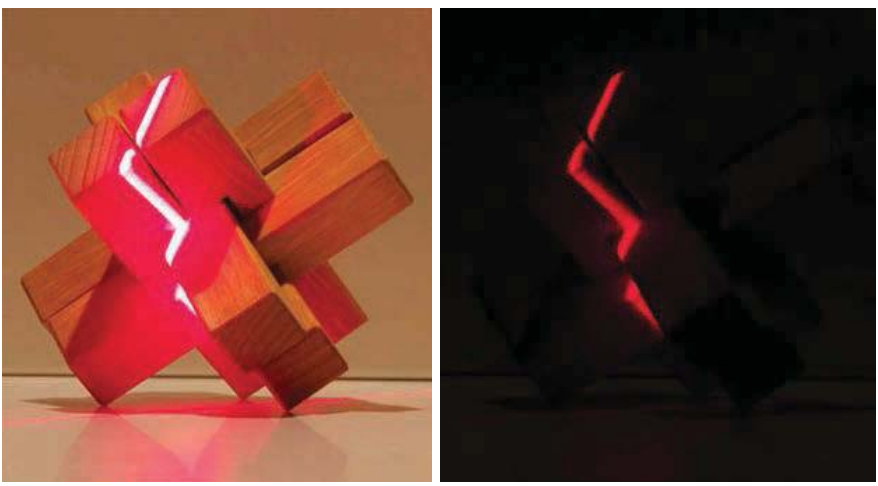
3D imaging refers to technologies that form 3D models of real items by using different kinds of imaging techniques. 3D imaging serves more information, with new possibilities to identify the target objects and especially their shapes. 3D imaging has developed a lot over the past few years. In smart health and social care, 3D imaging is used, for example, in physiotherapy to instruct the exercises or in surgery to guide the surgeon through the operation.

In most cases, 3D imaging is based on structural lighting, that is, the target is illuminated with some kind of a light structure, such as a laser line or a light dot pattern. There are also other kinds of 3D imaging techniques. This chapter introduces the basics of several 3D imaging techniques.

7.2.3.1 Laser Scanning

Laser scanning is an imaging technique where a laser line moves on the target or the target moves under a laser line. At the same time, the camera images the different shapes of the laser line as the line shape changes according to the target (Figure 7.12) (Batchelor 2012).

When the camera imaging and the move of the target or the camera are synchronized, the imaged laser lines can be combined with the analyzing software. The real 3D model of the object can be presented and analyzed with these combined lines. There are some limitations of this technique. For example, the 3D shapes can be detected only from the top plane of the object. In other words, if there are any shape changes on the bottom plane, they are not recognized. Sometimes, the need to move the camera or the target may cause problems with this technique. In addition, it may be difficult to illuminate deep grooves and image at the same time.



(a) (b)

FIGURE 7.12 3D imaging with laser scanning. (a) The laser line on the surface of the target object. (b) The shape of the laser line as the camera sees it.

7.2.3.2 Stereo Imaging

Stereo imaging is a more complex 3D imaging technique. It uses two or more cameras to image the same target from somewhat different viewpoints. A 3D image is created by combining the images taken from different angles. Combining images is a multiphase and complicated process. First, the correspondence of the matching pairs found in different images must be confirmed. Second, a disparity map can be formed with the correspondent points. Next, if stereo geometry is known, the disparity map can be converted into a 3D model (Marshall 1994).

7.2.3.3 Kinect-Based 3D Imaging

Kinect-based 3D imaging technology was developed for the Microsoft Xbox game console. It is used in game plays to monitor the players' movements in three dimensions. Because of the low price of the Kinect camera, it has become very popular in different kinds of consumer applications. The imaging technique of Kinect is based on two separate cameras: the traditional type of camera that takes images in visible light wavelength and the other camera that takes images in near-IR wavelengths. The 3D imaging is based on imaging the changes in a near-IR dot pattern that is reflected to the target surface. The target point distances can be calculated based on this information. Microsoft has released a software developer kit (SDK) for Kinect. It is possible to code your own applications with it. The Kinect camera can also be purchased separately, without a game console (Figure 7.13) (Kortelainen et al. 2013).

7.2.3.4 Fringe Imaging

In 3D imaging called fringe imaging, the target is illuminated with different lighting patterns. The shape of the target items can be detected on the basis of the changes in the lighting pattern. An example of a lighting pattern is presented in Figure 7.14.

FIGURE 7.13 Kinect camera for application development (back) and for game console (front).

FIGURE 7.14 Fringe structural lighting pattern on the target surface.

FIGURE 7.15 3D model of a human face by fringe imaging.

Figure 7.15, on the other hand, presents a 3D model of a human face made with a fringe-based imaging system (Batchelor 2012, Leino et al. 2015).

7.2.3.5 Time of Flight

Time-of-flight technology is based on measuring the time of flight of a light signal traveling between the camera and the target subject. It measures the time it takes for the light to travel from the camera to the target and back to the camera for each point of the image. In other words, it measures the light phase shift between the transmitted and received lights. A new-generation Kinect camera for the Xbox One game console is based on time-of-flight technology (Knies 2013, Kortelainen et al. 2013).

3D imaging technologies were mainly developed for industrial use, but they can also be applied to games, as shown by Kinect technology used in the Xbox game console. Commercial applications of these technologies are reasonably inexpensive and therefore more applicable in health and well-being sectors, too (Leino et al. 2015).

7.2.4 Nonvisible Machine Vision Technologies

Machine vision technologies described in earlier chapters usually refer to machine vision in visible light wavelengths, that is, machine vision solutions, which see about the same things as humans see. There are many imaging technologies for nonvisible wavelengths, and they can be integrated with the machine vision analyzing software to work automatically. This chapter concentrates on describing various special, non visible wavelength machine vision technologies such as IR imaging and spectral imaging.

7.2.4.1 Infrared Imaging

Infrared imaging is one of the best-known special machine vision system in non-visible wavelengths. Most of the research and applications still concentrate not only on long-wave infrared imaging, that is, thermal imaging, but also on near-IR imaging; near-IR imaging is already well known because of its special features. Thermal imaging has traditionally been used in finding hot or cold spots in processes, items, or environments. Lately, thermal imaging research has focused especially on automated quality control, on heating process optimizations, on search and examination of welding or casting faults (Figure 7.16), and on identifying contact resistance in

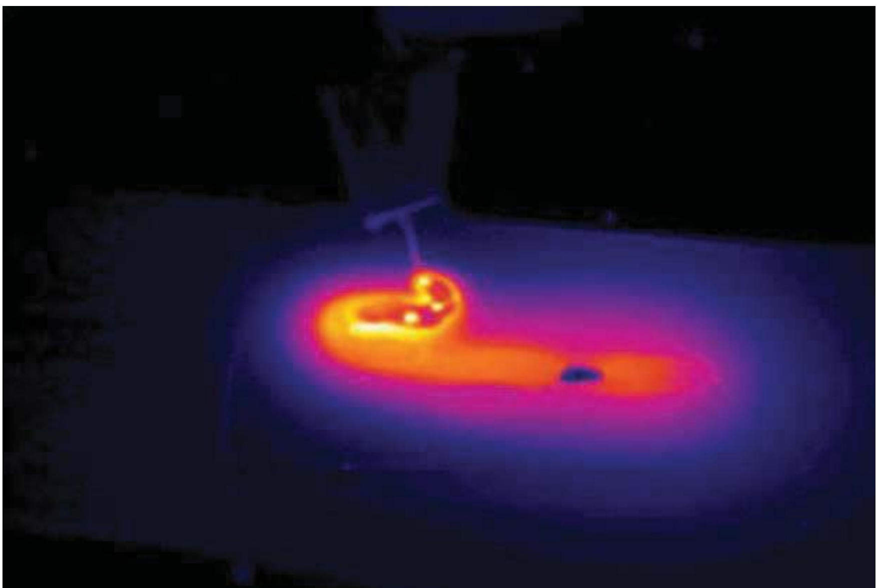


FIGURE 7.16 Faults in welding detected through thermal imaging.

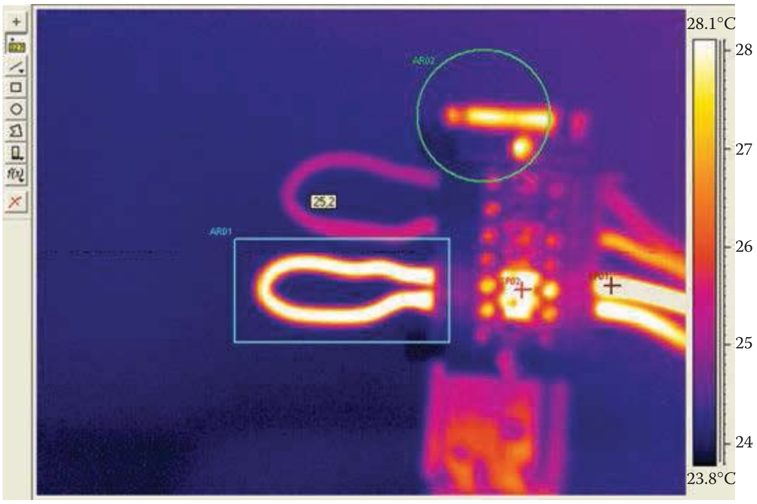


FIGURE 7.17 Identifying contact resistance in electrical connections with thermal imaging.

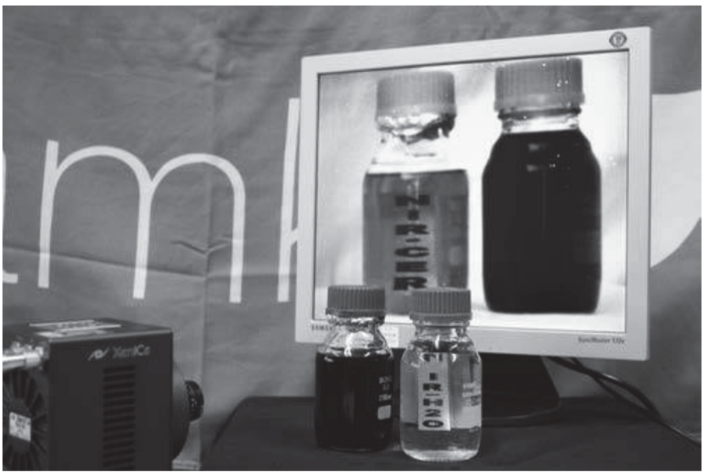


FIGURE 7.18 Near-infrared imaging used in moisture detection and in seeing through a kerosene-based liquid.

electrical connections (Figure 7.17). Near-IR imaging has been used mainly in moisture detection and in seeing through some materials invisible to the naked eye, for example, kerosene-based liquids, as shown in Figure 7.18 (Leino et al. 2015).

7.2.4.2 Near-Infrared Spectral Imaging

Near-IR spectral (NIRS) imaging is another type of very effective special machine vision technology. It is an innovative combination of spectroscopy, machine vision, and signal processing. Spectral imaging reveals the spectrum of the material at a certain point of an object from every pixel of the image. The spectrum also reveals the real color of the target object in visible light wavelengths. In the near-IR wavelengths, the spectrum is comparable to a fingerprint, identifying the concerned surface material

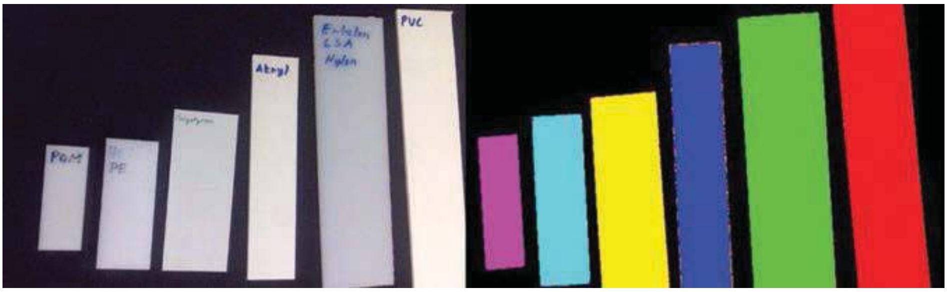


FIGURE 7.19 Plastics identified with near-infrared spectral imaging.

exactly. The spectrum identifies and visualizes each distinguished material that the target contains. Therefore, it is useful in identification and sorting of substances. An example of plastic identification is presented in Figure 7.19 (Leino et al. 2015).

7.3 MACHINE VISION FOR HEALTH AND SOCIAL CARE

As mentioned in Section 7.1, machine vision has traditionally been used in industrial applications. Its application to other fields has just started. The use of machine vision will increase with the proliferation of different kinds of service robots and automated assisting applications. The same development can be seen in smart health and social care. This chapter introduces a couple of machine vision applications designed for health and social care.

7.3.1 Separating Autism Spectrum Disorders with 3D Imaging

Autism is a neurodevelopmental disorder and consists of a spectrum of closely related disorders. Autism is diagnosed in patients who have problems with social interactions or in verbal or non verbal communication. They may also have restricted and repetitive behavior. It is very important to detect the symptoms of autism as early as possible to provide the most effective treatment for the best outcomes.

Obafemi-Ajayi et al. (2014) report how 3D facial imaging was used to detect the specific facial traits of autistic children. This 3D imaging system and the software designed for this purpose are considered good methods in defining the facial expressions that are common to children with autism. The imaging system is used to collect 3D coordinates of 19 facial landmarks. The distances between all possible pairs of these landmarks are then measured. As a result, the researchers captured 171 facial distance features. Complex software algorithms were used to categorize these viable biomarkers of autism spectrum disorders in subgroups.

7.3.2 Kinect-Controlled Physiotherapy

In physiotherapy, there are many treatments that are usually performed by physiotherapists manually. These treatments are often repeated on a daily basis for a prescribed period. Clinica Ordonez and Robotics Special Applications developed a robotic physiotherapy machine that can treat back problems in cervical, dorsal, and lumbar regions. The patients are automatically identified by their personal radio-frequency identification cards and the treatment is started. The Kinect-based imaging system is used to scan the patient's body shapes on the treatment area. The treatment can be carried out with the robot according to the physician's orders, with the help of the 3D model of the body (Riestra 2015).

7.3.3 Automated Venipuncture

Venipuncture aka venepuncture or venopuncture in medicine refers to obtaining an intravenous access for blood testing. Veebot (2014) is an automated venipuncture machine that combines machine vision and robotics. Veebot includes a table with an inflatable cuff, which fastens the patient's arm to the table and restricts blood flow, so that it is easier to detect the vein. Next, an infrared light is used to light the inner elbow, and the camera images it. The most usable vein is found from these images with the help of analyzing software. After that, an ultrasound is used to make sure that the vein is large enough and that there is adequate blood flow through the vein. Based on this analysis, the robot takes care of the needle aligning and of sticking the needle in. All these procedures take 1 minute, and a human is needed only for attaching the right test tube (Perry 2013).

7.4 MACHINE VISION CREATING FUTURE POSSIBILITIES FOR SMART HEALTH AND SOCIAL CARE

The earlier examples of machine vision in smart health and social care prove that there really is a clear need for new applications in this field. This subchapter compiles examples of the future possibilities of machine vision in smart health and social care. It introduces different applications under construction and considers the possibilities of different machine vision technologies for smart health and social care.

7.4.1 Kinect-Based Imaging in Enhancing Well-Being

The low-cost Kinect camera for Xbox 360 was designed for game playing, but it can also be used as a personal trainer. Microsoft released the SDK for application developers, offering a chance to create personalized application software. Kinect can be taught to give instructions based on observing the movements while exercising. Useful and personalized instructions on exercising correctly motivate to increase physical exercise.

An interesting example of 3D imaging applications designed for enhancing well-being is a Kinect-based human user interface. This application can be used to save personal movements in particular functions such as switching on or off electrical devices at home. For example, by lifting the right arm, the lights switch on, whereas by lifting the left arm, the light goes off again (Figure 7.20). This human user interface is usable as assistive technology or as a motivator in physical exercise. It is very easy to teach new movements to the Kinect application. In addition, it is easy to install the additional control electronics with interfaces to control intended systems (Leino et al. 2015).

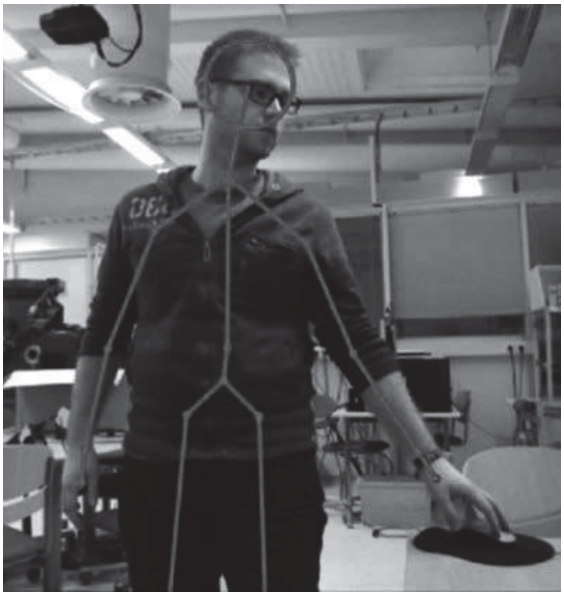


FIGURE 7.20 The Kinect application recognizes the user lifting his left arm and turns the lights off.

7.4.2 Infrared Imaging in Welfare Technology Applications

The special infrared imaging technologies have also been used in welfare technology applications. Near-IR imaging is applied and studied, for example, in perspiration detection and thermal imaging for detecting muscle temperature during and after exercising.

Figure 7.21 presents the findings of a very interesting study, where different cold therapy methods were tested and their effects on muscles were examined by thermal imaging. Three students used different cooling methods, which each applied on the calf of their left leg. The first student used cold gel (a), the second used cold spray (b), and the third used a cold pack (c). The right-side calves were imaged as the control reference.

The effects of various cooling methods are clearly visible through thermal imaging (Figure 7.21). The legs were imaged 15 min after the cooling method was applied. The findings indicate that cold gel and cold spray had no cooling effects at all. Only the temperature in the calf handled with a cold pack had cooled down measurably, even if in

FIGURE 7.21 Three different pairs of calves, where each left calf was cooled down with a different muscle-cooling method. (a) Cold gel; (b) cold spray; and (c) cold pack.

all cases the persons felt cooling sensations in their calves. The sensed effects can be explained by the fact that the gel and spray irritated nerve sensors on the skin and sent messages to the brain that the muscle is cooling down. This study confirmed only the measurable temperature changes in the muscle tissue. However, it could not be detected whether the feeling of cooling down caused any changes in the muscle (Leino et al. 2015).

7.4.3 Near-Infrared Spectral Imaging in Diagnostics

The usability of NIRS imaging in diagnostics has been researched in near-IR camera applications, for the use in the interface of welfare technology and electronics project at Satakunta University of Applied Sciences. The goal of the project was to find out if and how NIRS imaging could be used in inflammation detection on human skin or just under it. The secondary research question concerned about the possibilities of the technology to work better and more predictably than human eyes. In this project, the blood flow changes were detected, for example, in inflamed tissues, or skin grafts were researched through NIRS imaging. Figure 7.22 presents how severely inflamed tissues are shown on a person's left hand. Similar inflamed parts in terms of blood flow change are red in the spectral image of the right hand, where only some bruising could be detected by naked eyes (Huhtanen 2007, Leino et al. 2015).

Figure 7.23 presents a skin graft. The green color in an NIRS image represents deteriorated blood flow and blue color represents normal blood flow. Analyzed by NIRS image, these qualifications indicate that one part of the skin graft has healed better than the other (Leino et al. 2015).

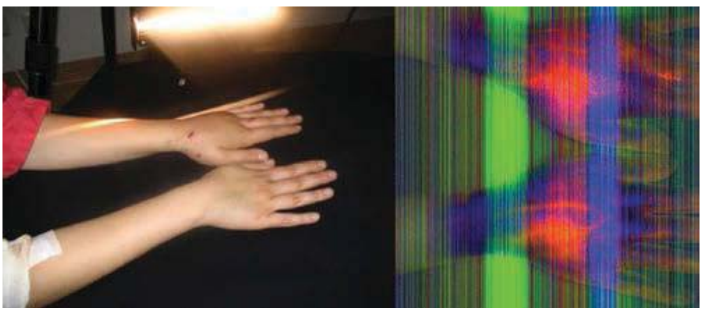


FIGURE 7.22 Septic hand (left hand) and a beginning bruise in the right hand in near-infrared spectral imaging.

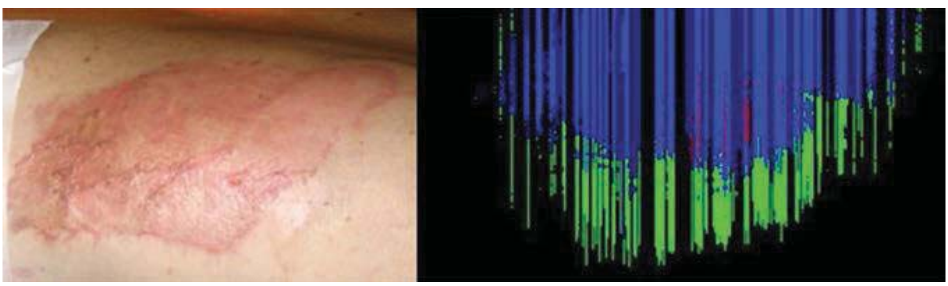


FIGURE 7.23 Skin graft in nature and in near-infrared spectral image.

7.5 CONCLUSION

Machine vision applications and their research have earlier been intended for industrial use. Today, there are several examples of how machine vision technologies known from industrial applications are also used in enhancing well-being. The advantages of machine vision compared with traditional methods have already been recognized in diagnostics or physical therapy, in particular, noninvasiveness and the possibility to image large areas simultaneously. Traditional machine vision technologies, particularly different kinds of special machine vision technologies, not only enable monitoring of health and well-being, for example, physical and physiological changes in a human body, but they also make it possible to recognize features and phenomena that humans cannot see. The well-known industrial base of machine vision creates opportunities to apply these technologies to new, innovative applications in completely different areas.

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VIII

RESEARCH COLLABORATION FOSTERING MUTUAL VALUE OF UNIVERSITIES AND SMES

by

Laine, Kari, Leino, Mirka & Lähdeniemi, Matti

Academic Proceedings 2016 University-Industry Interaction Conference: Challenges and Solutions for Fostering Entrepreneurial Universities and Collaborative Innovation

Research Collaboration Fostering Mutual Value of Universities and SMEs

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Abstract
Micro, small and medium-sized enterprises (SMEs) have a significant role in the European economy. There is a large number of innovative and entrepreneurial know-how in SMEs. In the European Union SMEs represent 99% of all enterprises (Entrepreneurship and Small and medium-sized enterprises). The key element of successful University-SME cooperation is to understand the business environment of SMEs from their perspective. SMEs have limited resources for research, development and innovation (RDI) and they usually do not have own R&D -department – often not even one person whose main job RDI would be. Therefore they need organisations they can collaborate with. Universities are expected to have a regional impact and innovating for or with SMEs is one way to accomplish the regional impact. There are European, national and regional policies that aim to support SMEs in their innovation and growth. Today there is a strong need to share good practices and to model successful collaboration. In that way new actors can benefit from it.

This paper introduces multiple case studies of how university can collaborate with SMEs and how both SMEs and Universities can benefit from the collaboration. Selected case studies are used to model the collaboration and its processes. Single cases are executed according to design science research process. Cases are also compared to find similarities and differences and to find model that fits most of the cases. The case descriptions concentrate on partnerships between universities and SMEs, technology knowledge transfer and also possibilities for knowledge intensive entrepreneurship originating from different types of partnerships. The paper also models different types of research collaboration.

Earlier research resulted one essential question for the future and it was how to develop the university SME partnership process so that the university is actively setting goals already in the beginning of the process to ensure actions that create the needed results for the university. As one answer, this paper also models different ways how University and SMEs can benefit from the collaboration. Most of the cases are production development processes with technology approach. This paper emphasizes how collaboration creates innovations, enterprises, entrepreneurial thinking, research publications and research spinoffs to name some of the results. Additionally this paper also shows that different modes of collaboration are giving direct and real time impact for refreshing and updating contents of university courses.

As a conclusion the paper shows how the collaboration helps universities to create strategic focal points for their research and to make their education more dynamic. It also points out how SMEs can add value by creating new innovations based on collaboration. This research indicates that in carefully considered collaboration, both, universities and SMEs, can create new networks they can benefit also in new ways.

Keywords
Research, collaboration, mutual value, univeristy, SME

1 Introduction

This paper deals with interactions between universities and small and medium sized enterprises (SMEs) and how the interaction can add value for both sides. The paper describes how additional value innovations work and add value to existing business. The SMEs are the main target group because of their known lack of resources in technology knowledge acquisition. In Finland SMESs consist 64% of employment and 60% of value added in non financial sectors (EU 2015). The situation varies in European countries but in general the role of SMEs is high in employment and value creation.

One of the main themes in technology transfer has been innovation. Instead of “just” searching and finding technology knowledge and transferring it to the enterprises as interpreted and enriched knowledge, the goal is to achieve a higher level of technology transfer in order to create targeted open innovations according to the new technology knowledge. It requires closer collaboration, mutual trust and shared research interests between SMEs and UASs.

One part of the closer collaboration is to achieve the shared innovation flow. The universities are responsibles in channeling all the partners to the shared innovation flow. The universities use different methods, like demonstrations and pilots, in knowledge dissemination in order to ensure that the technology knowledge of partners is in such a level that the shared innovation is possible. Demonstrations of certain technologies are made to illustrate the basic features, requirements and potentiality of the technologies, but they also highlight challenges of using the technology and exclude unsuitable solutions. Different kind of pilot cases are conducted on the basis of demonstrations and technology-specific but general level knowledge search. The subjects for the pilot cases always rise from the SMEs and they are implemented with university equipment as test applications. As a result, first-hand information is received from the pilots and they prove the potentiality or unsuitability of the technology in real environment.

In Finland the main drivers of University Business Collaboration (UBC) are mutual trust, short geographical distance, prior relation to the business partner, mutual commitment and a common interest of the stakeholders. The main benefits of UBC identified by Finnish academics are: improved employability of future graduates, improved learning experience for students, improved reputation in the field of research, increased funding and the improved performance of a business. The main barriers to UBC in Finland have proven to be: differing time horizons between a university and a business, the limited absorption capacity of SMEs to engage work placements or projects, the businesses lacking the awareness of the university research activities/offerings, the lack of financial resources of the business and the lack of university funding for UBC. The main benefits of UBC have been identified by the representatives of the Finnish HEI (Higher Education Institutions). According to them, UBC is seen vital in achieving the mission of the university, in improving the skills and graduate development. Furthermore, UBC has beneficial effects on the local industry, it increases local GDP and disposable income, and it creates local employment. Supporting mechanisms may be strategies, structures, approaches and activities. In Finland it is typical to have documented strategies with implementation plans. Collaboration is role-based and there are internal and external agencies focusing on it. Activities are, e.g. workshops for academics and students, networking, and promotional and project activities. (Davey et al., 2013.) Finnish universities have been active in university industry interaction.

The paper is organised into six chapters. In the following chapter 2 the background and theories in use are explained. Chapter 3 tells about research collaboration cases. Chapter 4 tells how they create mutual value for SMEs and for the university. Thus the main chapter explaining the research results is the chapter 4. The main results are summarised in Table 1 and explained more thoroughly in the text. The chapter is followed with chapter 5 where the results are discussed. Finally, the results are shortly summarised, conclusions are made and future research suggestions are given in chapter 6.

2 Background and theories in use

This research rests on finding and identifying mutual values rising from technology knowledge transfer processes between university and SMEs. The research is qualitative as its nature. The aim is to deeply understand the nature, processes and value created in interaction between university and SMEs in selected cases.

Earlier the technology transfer processes were extremely linear. The direction of the transfer was purely one-way. The transferred technologies were based on research results of universities (Harmon et al., 1997). In 2007, Perkmann and Walsh (2007) presented that traditional technology transfer between universities and enterprises has focused mainly on IP rights, patents, licensing and commercialization of the research results whereas the modern technology knowledge transfer means much wider actions with different operation channels and mechanisms (Perkmann and Walsh, 2007).

Bradley et. al. (2013) state that traditional linear technology transfer models have come to the end of their lifecycle. These models will not work anymore in the enterprise and university culture of the future. The diversification of business models and the renewal of the university research commercialization possibilities have led to this point where technology transfer needs new models. The universities must create their own technology transfer models that suit best for their operations with the SMEs. (Bradley et. al., 2013)

The background of this research is also in the results of earlier technology transfer research projects executed at Satakunta University of Applied Sciences from 2008 to 2014. These research indicated that both the university personnel as well as the students and the personnel of the partner enterprises seem to learn a lot in the collaborative actions. The research also showed that partnerships help to create targets for open innovation processes and to create research-based knowledge to support innovation processes in industry. However, the research recommended that higher education should set its own goals from its own point of view and set the goals already in the beginning of the process. This way the university could be an equal partner for industry when both have their set goals. (Laine et.al., 2015; Leino et.al., 2015)

Learning is a central element of innovation in organizations (Nonaka and Takeuchi, 1995; Lundvall, 1992; Etzkowitz, 1998; Laine, 2008; 2009). This research examines what kind of mutual values the technology transfer process with learning and innovation as key elements can create to the university, the students and the enterprises.

This research focuses on technology transfer processes with partner enterprises and with potential future partner enterprises. Satakunta University of Applied Sciences has its own best practices based partnership model. When evaluating this model it was found that in successful partnership it is important for partnerships to understand the importance of trust and of creating trust, to make clear goals for the partnership, to agree on operational actions, to perceive time scales, and to create concrete results with mutual benefits for university and industry. So, in order to develop the partnerships it is also important to find mutual values of the technology transfer processes. (Leino and Laine, 2014, Lähdeniemi et al., 2012)

2.1 Design science research

The technology and knowledge transfer development and modelling is based on design science research which is actively supported by action research.

Design science research is a research method based on problem solving paradigm. A design science research process concentrates on innovations. There must be a clear need, which is answered by design and construction creativity of humans. At the same time one goal is to identify the creativity of designers and engineers and to benefit it in application development. (Hevner and Chatterjee, 2010)

Hevner et al. (2004) state that the design process of an artifact itself creates new knowledge and understanding. They define articulate guidelines for design science research process:

(1) Design as an artifact

(2) Problem relevance

(3) Design evaluation

(4) Research contributions

(5) Research rigor

(6) Design as a search process

(7) Communication of research

First of all, the whole design science research process rests on an idea of an artifact that should be designed. The recognised problem should be relevant. The problem relevance is defined for example by comparing the present state and the future state of the artifact and defining the relevance of the change between these states (Hevner et al., 2004).

The analysis of the artifact's usefulness, quality or/and effectiveness creates the basis for the evaluation phase of the design. The evaluation methods may be observational, analytical, experimental or descriptive. There should always be a clear result like new artifact, new knowledge and/or novel method in design science research. Research rigor refers to the rigorous construction and evaluation methods used in the research work. It is very important to choose appropriate techniques to design and methods to test and evaluate the artifact. (Hevner and Chatterjee, 2010).

Eventually the whole design process is a knowledge search process where useful and available methods are used to find requisite information needed to accomplish as practical solution as possible. It is essential to introduce all the significant knowledge risen from the design work to both technology-oriented and management-oriented groups of interest after the design process. (Hevner et al., 2004).

2.2 Action research

This research utilises also action research theory in research design. Action research was developed by Lewin (1946). This research uses basic phases of action research defined by Susman and Evered (1978): diagnosing, action planning, action taking, evaluating and specifying learning. The research design uses three phases of inspection, imagination and intervention (Kallenberg 1995). Inspection means finding similar organisations or situations where new approaches can be learned. This can also be called as benchmarking. Imagination means that feasible and desirable alternatives are found. Intervention stands for intervening with others to improve the subject at the same the study about it is conducted.

The study uses triangulation in theory, methods, cases and evaluation.

3 Cases for research collaboration

This chapter tells about three example cases. The automation research group of Satakunta University of Applied Sciences collaborates annually with 30 enterprises and works with 30 to 40 cases. In this research the modelling is based on experimental steps executed in cases with enterprise partners in 2014-2015. For this research 18 cases executed with 16 enterprises were selected for closer examination. Cases were selected so that different types of interaction and methods for collaboration are used in cases. So, the best practises can be identified from these cases to support the model construction. In this way deep understanding of interaction, methods, processes, outputs and outcomes can be obtained. The model is build from true cases and their evaluation. The basic interaction process between university and enterprises is described in Fig 1.

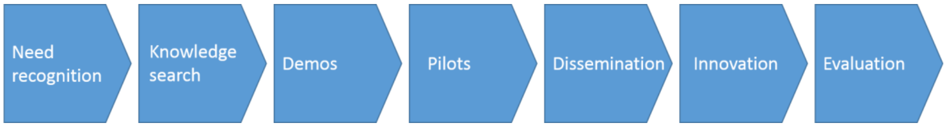

Figure 1: The Interaction process between university and enterprises

The case examples A, B and C in this paper have been chosen from the 18 cases of this research in order to introduce different procedures and methods of the processes.

3.1 Case A: Reading inconsistently located barcodes and QR codes

A partner enterprise connected automation research group with a production logistics related problem: How to read inconsistently located barcodes and QR codes on large products in order to follow the products during the manufacturing? The enterprise had already asked the technology suppliers and they did not have solutions to offer.

This case had a simple but for the enterprise significant result. The researchers at the University of Applied Sciences prepared an illustrative demonstration. They demonstrated how a machine vision system can image a wide field of view, see even the largest products in one picture, read the barcodes and matrix codes as well as measure the dimensions of the product in less than 20 milliseconds (Fig 2). The demonstration showed distinctly how the product identification and measurement should be done simultaneously in this case and the enterprise got all the information that they needed in order to acquire a workable solution for their purposes.

For the researchers this case gave more knowledge because they studied many possibilities to do this kind of machine vision based code reading application and found the best practices for it. At the same time the demonstration is also a useful example in the engineering education.

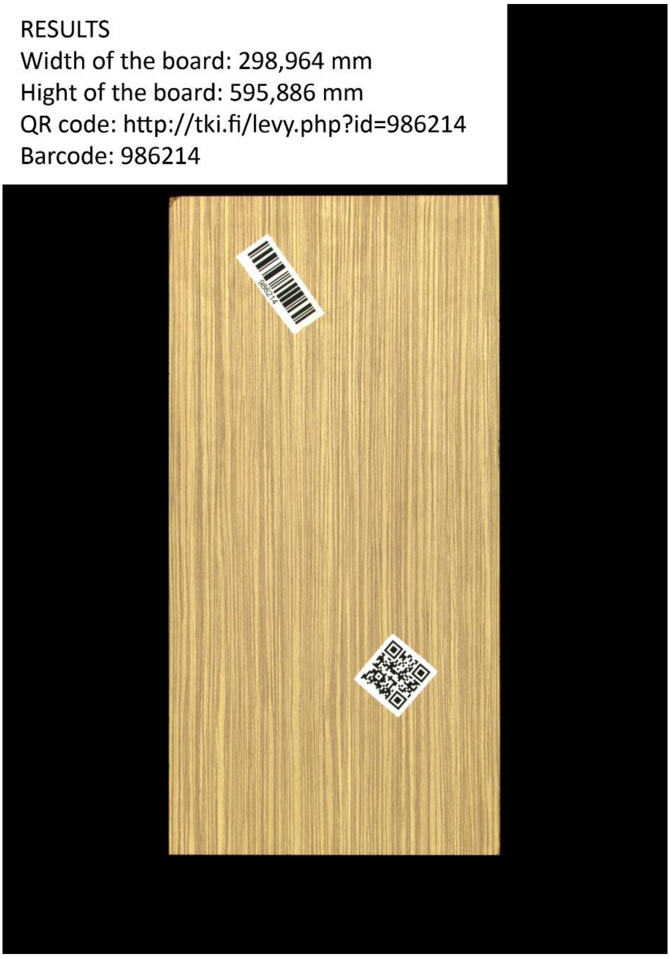

Figure 2: Example result of the demonstration reading codes and measuring dimensions.

3.2 Case B: Specular reflection lighting for machine vision based inspection

In Case B the enterprise had also a machine vision related challenge on their packaging line. They planned to use machine vision in quality control of a highly reflective cellophane package. The automation research team identified immediately that the imaging process is challenging. The varying shapes of the cellophane surface cause varying reflections, where some points of the image are overexposed and some can barely be seen. This required some innovative tests and research together with out-of-the-box-thinking.

As a result the team designed an innovative specular reflection lighting with 100 LEDs emitting light from slightly different directions. The reflections from different directions are exploited and put together in the result picture. With all the possible reflections put together the result picture shows clearly the spots, which do not reflect at all (Fig. 3). If there is no reflection at all, there must be a tear in the cellophane package.

Again this research case gave the required information and knowledge to the enterprise but it also gave many new ideas and technology knowledge to the researchers. This innovative lighting system will be used in several other application in the future.

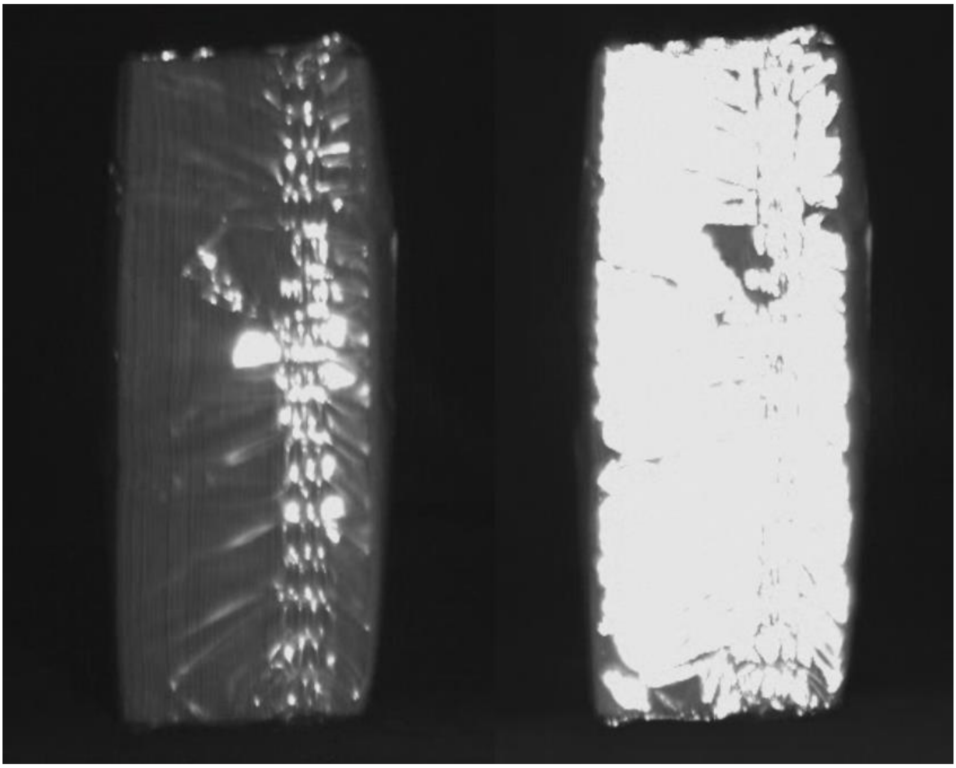

Figure 3: Examples of the cellophane package lighted with one LED (on the left) and lighted individually with 100 LEDs and all 100 pictures merged together (on the right). The defect can be seen as a black area in merged picture

3.3 Case C: Customized shoes with the help of 3D imaging and 3D printing

In this research case C the enterprise wanted to find new methods for making individual shoes for persons with specially formed feet. The research was implemented in collaboration between shoe manufacturer, a vocational education institute and the university research team. The research was started with testing different 3D imaging technologies in order to create a uniform 3D model of the special foot. The imaging tests were made with a boot-tree and several 3D imaging technologies. A structural lighting based 3D imaging technique was found to be the most suitable for this purpose and the 3D models of the boot-trees were generated with it. After this the new boot-trees were 3D printed with Fused Deposition Modeling technique. The shoemaker teacher from the vocational education institute made the shoes onto the 3D printed boot-trees.

The next phase of this research was to make the special shoe soles for the shoes. First the bottoms of the shoes, made by the vocational institute teacher, were 3D imaged and the images were used in 3D modelling of the shoe soles. The last phase of the research was to find usable flexible plastic material to be used in 3D printing of the shoe soles. When the adequate flexible plastic material was found the shoe soles were 3D printed and the shoes are now in use. The person with the special shoe needs is testing the usability and the durability of the shoes.

For the enterprise this case C gave valuable information about the usability and exploitability of 3D imaging and 3D printing technologies in shoe making. Price indication even for single manufactured product encourages utilisation of 3D technologies in large scale. The research group strengthened its knowledge on 3D printing of 3D imaged objects. Especially the details, which increase accuracy in scanning based 3D imaging, could be of identified and thereby the outcome of 3D printing could be enhanced. At the same time this case gave meaningful information of using flexible plastic materials in 3D printing and of the usability and durability of these materials.

4 Fostering mutual value

This chapter summarises the main findings of this research. The goal of this research was to find mutual values achieved in collaborative research and development processes between SMEs and universities. The mutual values are identified in order to foster shared innovation creation processes and collaboration. One significant part of the research was also to enumerate values from the university’s point of view. With the identified values the wider meaning of the collaboration can be done more visible.

The next table describes the mutual values identified in evaluation of the 18 technology research cases in this research. The values are tabulated by the steps of the interaction process and by the beneficiaries.

CREATED MUTUAL VALUE	**For Enterprises**	**For University / Researchers**	**For Educators / Students**
Need recognition	Identified and classified needs	Knowledge of needs and problems	Knowledge of professional know-how needs
Knowledge search	Focused facts and methods	All new knowledge and knowledge sources	Up-to-date expertise
Demonstrations	Understanding and new ideas	Experience based knowledge of possibilities and obstacles	Prepared demonstrations and learning environments
Pilots	Hands-on experience, recognising possibilities, challenges and unfit applications	New knowledge and knowledge sources	Real industrial development possibilities
Dissemination	Knowledge to support investment and development planning	Dissemination knowledge and methods	Interest and motivation
Innovation	Practical, supplier-independent solutions	Knowledge of targeted open innovations	Examples and experiences, entrepreneurial thinking
Evaluation	Understanding of possibilities and obstacles	Best practices for modelling, understanding of enterprises and needs, publications	Subjects for publications, topics for thesis works

Table 1: Created value for the participants in different phases of the collaborative research process

The need recognition requires mutual trust but it also gives important information. Enterprises get identified and classified knowledge of their research and development needs while the researchers of the university get to know the current development needs and real working life problems. And when this knowledge is disseminated to the university students, they have more precise information of the current needs of professional know-how on specific fields of local enterprises.

Knowledge search done by the researchers aims at finding the newest research results for the identified needs. For the enterprises this process gives facts about knowledge sources and methods of knowledge search. The researchers do the main work in this phase. They increase their expertise in the field of current technology research but also find new knowledge sources. Again, efficiently disseminated results of the knowledge search give up-to-date shared expertise of new technologies to the engineering students and educators.

In dissemination of new technology knowledge the demonstrations have a significant role. By concrete demonstrations the enterprise representatives can create understanding and new ideas through real world examples. On the other hand the researchers creating these demonstrations get useful experience based knowledge of possibilities and obstacles of applying certain technologies. And, this way the educators have always fully prepared illustrative demonstrations and learning environments for education purposes.

The technology demonstrations and need recognition often create needs for pilot solutions. They are done to pilot certain technologies in some specific industrial targets. The pilots are always done with university-owned machines and equipment if possible and they give the enterprises hands-on experience of applying certain technology to certain identified problem or development need. The pilots show the utilizing possibilities of the technology as concretely as possible, introduce the challenges of utilizing the technology as well as exclude unfit applications. Again, the researchers as designers of the pilots get new knowledge and knowledge sources for technology research and the students get possibilities to join in real industrial application development processes during their studies.

The dissemination could be stated as the core phase of the technology transfer process. It is mainly directed for the enterprises. The purpose is to disseminate significant knowledge that can be used for example in planning the investments and development projects of the company. From the researchers' and universities' point of view the dissemination step gives knowledge of targeted dissemination as well as new dissemination methods. Both the educators and students can increase their understanding of the principles and utilizing possibilities of the technologies. Moreover, a devoted educator produces interested and motivated students.

The knowledge search, demonstrations, pilots and knowledge dissemination lead more than likely to innovations. This kind of multiphase, university-responsible path to innovation ensures that the enterprises get practical, supplier-independent solutions for their development cases. The innovations are often results of a collaboration and thus, the university researchers get useful knowledge of targeted open innovations in enterprise collaboration. And, the participating students get examples of innovation and experience of participating an innovation process. While the students experience innovation processes, their entrepreneurial thinking is developing and spin-offs are more likely to emerge.

> *"I just wanted to tell you first, that our startup is born. We believe that after a month the proto app will be in the state that we are able to search VC for finalising it. We would like to demo it for you and send our best thanks for the significant support in the initial stage*" (message from a partner in technology transfer)

Lastly, the evaluation of the entire technology transfer process is done by reflecting all the beneficiaries. The evaluation helps the enterprises to understand the possibilities and obstacles in utilizing new technologies. At the same time the university and researchers can identify best practices for model construction as well as get to understand different enterprises and different needs in technology research and development. For the researchers, educators and students the evaluation gives subjects for publications, plenty of topics for thesis works and through the increasing expertise, ability to tutor more and more challenging thesis works.

5 Discussion

This chapter discusses on the results presented in the previous chapter. By evaluating the table of mutual values (table 1) it can be seen that mutual value here means that the university and enterprises work together towards a shared goal and different parties benefit from the results differently. For example a scientific literature review may give wide-ranging new knowledge for the university, whereas even one significant research paper, found in this process, may give answers for the enterprise's specific need. Knowing these similarities but also the differences helps the university to set their own goal already at the beginning of the research.

In this kind of multi-phase technology transfer process the university can understand the business ambitions of the enterprise and at the same time the enterprise can understand the university's actions in their fields of know-how like research and development.

To understand business from both enterprises' and research and development's point of view is a basis for knowledge intensive student entrepreneurship. When students participate in different actions of technology transfer, evident orientation to spin-off entrepreneurships is happening.

This research proves that the demonstrations and piloting have a significant role especially in collaboration with SMEs, because the concreteness of the examples convince SMEs about the importance of the research results. This is important, because traditionally SMEs may have difficulties in absorbing research information and they do not have product development of their own. With the help of the demonstrations the enterprises understand how they can apply certain technology for their specific needs. This really guarantees that SMEs participate RDI projects with clear needs.

For sure, this kind of development and actions of technology transfer have their own country-specific, regional and structural change combined features, which must take into consideration when applying these action in new regions.

Working with dozens of SMEs annually helps the research group to fine tune their research to directions that can help local SMEs in short or medium time scales. Inside the university it can be seen that other research groups are actively looking for collaboration with research groups that have active collaboration with SMEs. They want to have their share of the created application and innovation capacity. Collaboration has created new networks for both university and SMEs that have potential for new collaboration and creation of innovations.

6 Conclusions and recommendations

This chapter shortly summarises the results, gives some limitations and opens views for the future research. The study showed that described collaboration can create innovations for SMEs. It also created dynamics into university research and education. Created new networks have potential for future innovations as well.

This study was based on collaboration of one university with many SMEs. It was conducted on a region that has had it difficulties with structural change from traditional industry to more service based industry. The culture on the region is not very collaborative, but the enterprises have very consistent way of working towards their goals. Creation of trust has taken time, but the results are rewarding. The collaboration refreshes the innovation activity and business structure on the region by opening views for new research based and business focused startups.

The trust creation was essential. Therefore, the creation of trust and time it requires should not be underestimated. However, when succeeded the researchers rise to a new level in applied research when they understood the business of local SMEs. They could have more creative thinking how specific technologies could be used not only in business they understand but also in new areas. Collaboration also made university education more dynamic because new contents could be added to ongoing studies but also development of curricula is based on needs of SMEs and not on general views of development.

Based on this research, it is worth asking what SMEs need. SMEs can tell their challenges, but they are seldom able to tell how to find the right answers. Therefore collaboration and need recognition is an important starting point in finding the focused areas where the university can add value. Pilots were seen as essential for SMEs to understand the opportunities created by new technologies.

Modelling this kind of innovation collaboration is demanding because of its multiple limitations and preconditions. It may have limitations based on country, region, collaboration culture, industrial structure and state of development, structural change needs of the region and university structure. This triggers several new needs for future research.

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