University – Industry Collaboration Concept for Master Thesis Projects, Learning Outcome and Knowledge Triangle Development

O.J. Mork
Associate Professor
Norwegian University of Science and Technology - NTNU
Ålesund, Norway
E-mail: ola.j.mork@ntnu.no

I. E. Hansen
Scientific assistant
Norwegian University of Science and Technology - NTNU
Ålesund, Norway
E-mail: irina-emily.hansen@ntnu.no

P.S. Kleppe
Assistant Professor
Norwegian University of Science and Technology - NTNU
Ålesund, Norway
E-mail: paul.s.kleppe@ntnu.no

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INTRODUCTION

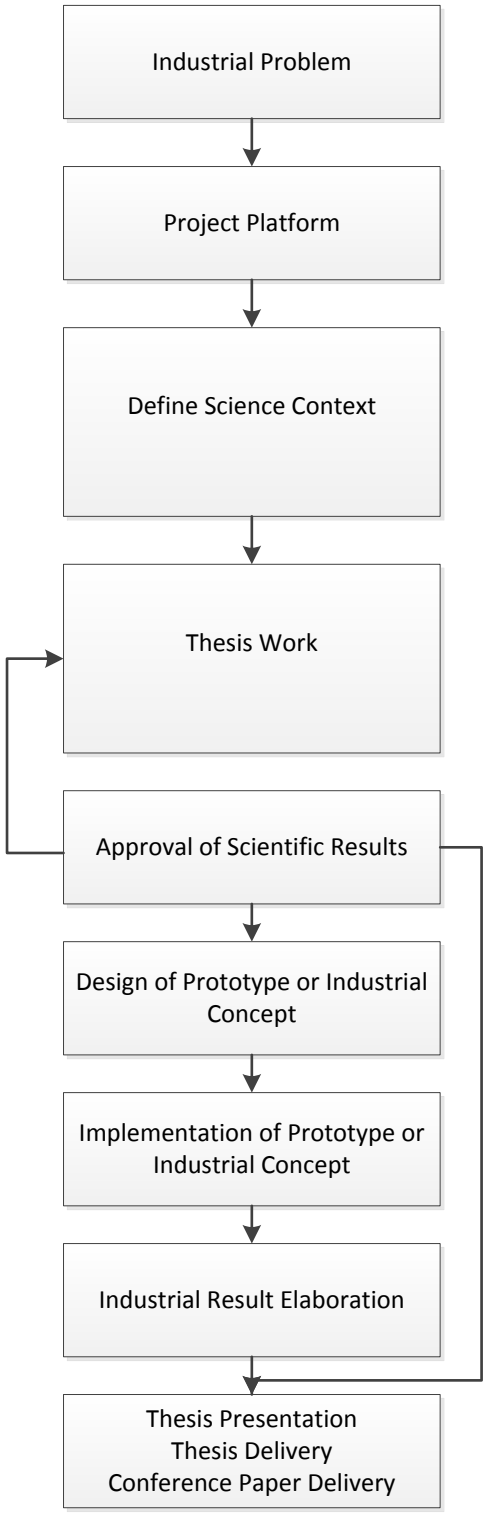
The global competition in industry demands new business models, new products and more efficient manufacturing concepts. A crucial factor for the industrial companies is the development of knowledge and skills inside the company and the possibility to recruit students who are well prepared to create value for the company. Continuous research work is also crucial to create new knowledge and speed up the innovation for the companies. The universities have to take a leading role in this knowledge development, connecting education, research, industrial innovations, and more precisely orchestrate the Knowledge Triangle [3].

Engineering students who undertake a 5-year Master program acquire quite much knowledge about engineering methods, tools and technology, but how can they learn more about the application of engineering and technology in an industrial setting? Industry is actually a network of companies such as suppliers and customers as well as a number of industrial systems and the organization of this can be a labyrinth. Earlier research [5] has discussed the demand for Short Industrial Placements for Master Students, and how an SIP Activity Framework can be made. Christiansen et al. (2014) [2] introduce how interdisciplinary student groups work with Small and Medium Sized Companies, and what are the challenging issues. Abdoel et al. (2014) [1] introduce the Work field Orientation Module, where the purpose of the module is to broaden awareness about the non-technical skills useful for the students at the start of their carriers.

This paper sets out to explains how collaboration between university and industry in master thesis projects supporting the Knowledge Triangle, can be designed and how it can be put into practice. The master thesis projects combine academic learning at the university and more practical learning on the factory floor, explained as a Hybrid Learning Environment [6].

The paper is based upon experience with thirty University-Industry master thesis projects completed over a period of four years. The paper is triangulated with three lecturers, two students and two industry leaders, who all have participated in the development of the concept.

1 MASTER THESIS DESIGN AND HOW TO PUT THIS INTO PRACTICE



1.1. Industrial problem is the foundation for the master thesis

1.2. Project Platform
- Project Planning
- Project Team
- Long term Cooperation
- Minimum two parallel master thesis running

1.3. Define Science Context Theory
– "State of the art" survey in industry and science,
- Defining objectives both for industrial- and science
- Formulate Work Research Question
- Elaborate the most appropriate research method

1.4.. Thesis work
- Collection of the best data in a smart way
- Present the data in an "easy to read format
- Analyze the data
- Elaborating and defining the scientific result

1.5. Approval of the scientific result.
- Point out the direction for solving the industrial challenges

1.6. Design of a prototype or design of an industrial concept or system for testing,

1.7. Implementation of a Prototype or an industrial concept at the University Lab or on the Factory Floor

1.8. Industrial Result Elaboration – and Testing performance of the prototype or the industrial concept

Fig 1 Flow chart of the University – Industry Collaboration Process

1.1. Industrial Problem

The industrial master thesis project is rooted in industrial operations and systems. An industrial master thesis can be within product development, product architecture, process development, technology development or industrial systems. The scope of the master thesis project has to be narrowed down to an appropriate size, and it cannot include too many different issues. The student is responsible for defining his master thesis project in cooperation with the company and his lecturers. The master thesis project includes both an industrial and scientific objective, which is developed in the first stage of the work. Most of the industrial master thesis project is a typical case study. Design of a concept, prototype or a small-scale process is obligatory, and most of the students also build a product – or process demonstrator in the lab or implement it in small-scale processes in the industrial company. Implementation of processes requires a close cooperation among the partners; the university, the industrial company and the student.

1.2. The project platform

The project platform for the university-industry master thesis seems to rely upon a number of key factors. The first factor is the cooperation between the university and the industrial company, which should have at least three years' perspective. Within such a time frame the university can build knowledge about the industrial company, their organization, products, processes and business, and the industry can acquire knowledge of academia, how it is to work with education and what the students are able to do within the time frame of the master thesis. The second factor is having two or three master thesis projects running in parallel in the same industrial company. The students can take advantage of each other's experiences with the industry and the university can also put more effort into one industrial relationship. The industrial company can "connect" the master thesis projects together, to pursue a complete industrial project and create more substantial industrial results. The third factor is a common and thorough preparation of the master thesis projects by both the industrial company and university, which is important. The master thesis subjects and the project planning should be made at least 6 months before the master thesis project starts. When the industrial company and the university have common experience with master projects, they gain knowledge about how to improve the next collaborative project. The fourth factor is creating a project team of a minimum of five key stakeholders from the university and the industry. Typically this includes three employees from the industrial company, at least two lecturers and maybe an external stakeholder with interests in the project. This can be a supplier or a customer of the industrial company. Project planning is an important part of the master thesis project. There are three partners involved in each project; the industry, the university and the student, and successful performance requires common work and motivation. With a limited time schedule, the project plan must nevertheless include a well-planned "activity – time – responsible" schedule.

1.3. Defining the scientific context

This can be a challenge for the students, but for the university–industry collaboration project a science library is created. A small library of "standard literature" is located at the lab, and there is also a "standard digital library" accessible to the students. Based upon this they can go on and seek more detailed literature. However, it is also necessary to study "state of the art" industrial components, systems and solutions, when the students

are building prototypes and concepts. Already in the beginning of the master thesis project it is pointed out that the importance of fulfilling to “two purposes” – a knowledge gap in the science and the industrial result (innovations). Some effort is put into formulating the research questions, but there is a rather soft approach when it comes to sharpening the questions. More effort is put into research objectives. It is important to start the process, see what data is collected and then narrow the focus. Attention to the research method has grown through the experience of the university – industry collaboration concept. There is still potential for development of the methods, and smarter research methods are one of the key drivers for better results.

1.4. Thesis Work

Data collection in an industrial environment can be demanding for the students, especially if they have minor industrial experience and knowledge of industrial organizations and systems. If the project is embedded in the organization, this will support the project execution and data collection. It is an advantage if the student can use existing guidelines or framework for the collection of data, especially if data has to be collected on the factory floor, where there is a very rich information environment and processes are running constantly. Too much data will cause confusion for the student, and also for the other stakeholders of the company.

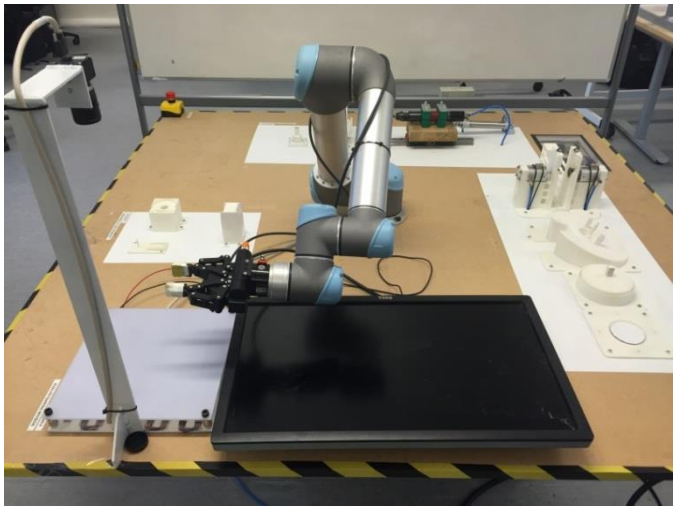
Analyzing the data and proposing directions for the creation of a prototype or industrial concept is an exciting part of the project, where you can find unsolved issues and come to the root cause of the problem. In this phase of the industrial master thesis projects the students are trained to present and visualize the key findings several times. It is so important that the students are able to identify the real problem, if they are to be able to find the right solution.

Presentation of data can be done in so many ways; it can be figures, movies, interviews, and other smart solutions. Elaboration of the results and conversion of them into science can only be could also involve the team connected to the master thesis project.

1.5. Approval of the scientific result

The scientific result is presented to the project team in a meeting, where it is approved as a foundation for further work on a prototype or an industrial concept that will solve the industrial problem. The direction for a how a prototype or an industrial concept can be created is pointed out.

1.6. Design of a prototype or an industrial concept



When the scientific result is approved, the next step is to develop a prototype or an industrial concept that can be tested in the laboratory or in the factory. Example of a prototype can be a small scale robot cell, a new product or a lean manufacturing concept.

Figure 2: Prototype of Robot-cell installed at the factory floor

1.7. Implementation of a prototype or an industrial concept

Prototype testing or industrial concept testing in the University Lab is an exciting learning phase of the master thesis project. Lead users from the industry are hired in to test the prototype, figure out how it can be improved, and take out the innovation potential from the research. Normally these tests are video recorded so they can be studied at a later stage.

Prototype or Industrial concept tests on the factory floor are even more demanding. These are done with the engineers and operators from the industry involved in the testing. However, with thorough preparation and follow up, these tests are really a learning environment for the students. Performance is measured. The prototype and concept tests are normally repeated several times, and also system tests are often split up into several sub system tests.

1.8. Industrial result elaboration

The industrial results are elaborated in a number of separate workshops. This is a very important part of the project where new knowledge is developed especially in terms of industrial understanding. In this final stage of the master thesis projects, the next stage is defined. This can be a new master thesis project or a research project or even to build an industrial version and implement the result permanently on the factory floor.

2 LEARNING OUTCOME

2.1. The Student

During the industrial master thesis project the student acquires a variety of both theoretical and practical knowledge. The students have access to the university's rich theoretical knowledge, the research labs, and the academic staff. Students learn how to solve research issues and explore new knowledge and how to combine theoretical and practical knowledge into industrial applications or innovations [4]. Since the students build

prototypes and industrial concepts and implement these on the factory floor, they acquire a deeper learning and reveal new challenges and research issues.

An industrial company is not only about engineering; it is about organizations, suppliers, customers, machineries, and maintenance and industrial systems [3]. The student acquires valuable experiences with how to deal with a network of stakeholders, industrial organizations and cultures. The students learn also about project management and get insight into financial - and organizational issues. The students acquire understanding about the interrelation between product design and production processes. The students experience also the importance of involvement of both technical - and financial knowledge at the early stage of the project. .

Industry is engaged in competition every day, and in high cost countries every employee has to deliver value for the customers every day. This can be quite challenging for students coming directly from university, since they have to learn the industrial systems before they are able to deliver value. An industrial master thesis project gives them a first introduction to their next step in life, working as an engineer. Many of the students are able to create a “small industrial network” during their master thesis project, which they can draw on when they enter their first job in industry. The students learn also how communities of practice work inside the company and how they can get at the inside of these organizations [7].

2.2. The Industrial Company

The industrial company acquires knowledge from the students and from the lectures during the master thesis project. An interesting effect is that in many cases the students’ work is a learning kick for the organization, especially the testing of prototypes or implementation of industrial concepts on the factory floor. This stimulates a combination of the operator’s knowledge and theoretical knowledge around an object [4]. The master thesis contributes also with industrial results in most of the cases, especially when the company has gained experience with master thesis projects. Good preparation and thorough follow up of the master thesis projects will definitely support the knowledge diffusion inside the company. It is important that all the stakeholders have been involved in the project from the start.

One key issue is how good are industrial companies at acquiring the students’ theoretical knowledge, and converting it into industrial results. This is also an interplay the industrial company can develop with the students and the lecturers at the university. Some industrial organizations can even catch the students’ most theoretical learning, and follow it all the way to its application on the factory floor. Other industrial organizations need more hardware, like an implemented prototype or process before they can acquire the knowledge and combine it with their own industrial knowledge. However, these abilities are developed step by step when the cooperation between the university and the industrial company lasts for a number of years.

2.3. The University

The learning outcome for the university is up to date knowledge about industrial companies, their organizations, product, processes and network. Close interaction also gives insight into what type of knowledge the industry needs and what the core

competence the engineers need now and in the future. It is also important for the lecturers to see how theoretical knowledge is applied in the industry, and how organizational learning is taking place in the companies. Leading industrial companies rapidly develop new products, new processes and new components, which in many cases are in the forefront of the academic research. In this respect, it is important for lecturers to follow industrial research and development.

3 INDUSTRIAL MASTER THESIS PROJECTS AND BUILDING THE KNOWLEDGE TRIANGLE

University - industry collaboration for master thesis projects complies with the European economic growth strategy and supporting program, Horizon 2020. The active interaction between research, education and innovation is pointed out as a condition for Europe to meet long-term challenges of the competitive global economy, according to the European Council (2009). The importance of the strong dependence of these three elements on each other has been emphasized by their unification in one model called Knowledge Triangle (KT). Collaboration between different stakeholders of the regional economic environment, both from industry and public sector, is crucial to make KT function efficiently. Universities are challenged to play a managerial role in this collaboration. Conducting master thesis in an industrial company actualizes the application of research and education in real life and initiates innovation. Innovation necessitates the emergence of new research and speeds up the upgrading of educational content and methods, which in turn creates new collaborative projects contributing to the continuing development of research, education and innovation.

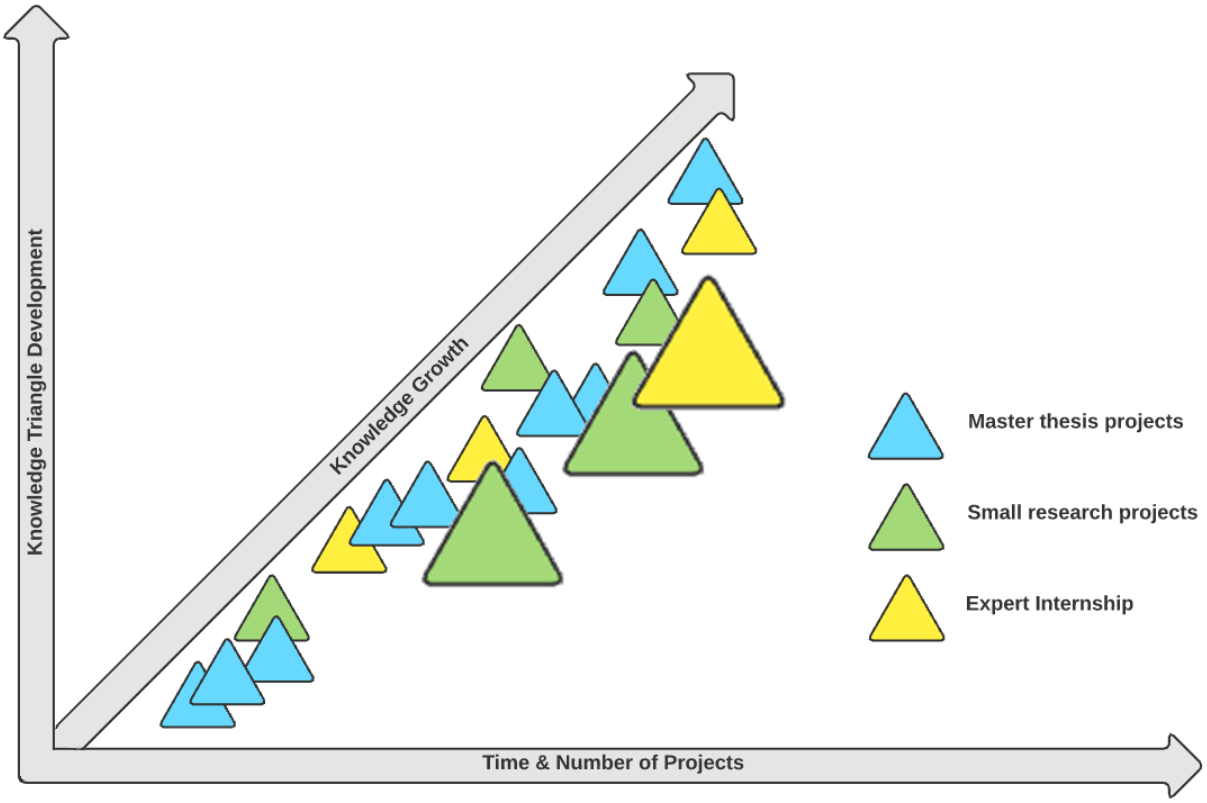


Figure 3. University – industry collaboration building the Knowledge Triangle

First of all, the industrial master thesis projects connect education, research and innovation. Education is obvious, but it also includes research work, and since the industrial company applies the new knowledge it is an innovation. There is also a strong commitment among the actors to creating successful projects, and it is a long-term relationship where multiple master thesis projects are connected.

The master thesis projects are building strong relations between university and industry, and it opens up new activities. One example is that highly skilled engineers from industrial companies are giving lectures to the students at the university in industry related subjects. Lecturers and researchers from academia can also do long term or short-term jobs in industry.

The master thesis projects are followed by new master thesis projects, which are connected. Master thesis projects are often followed by both small and larger research and innovation projects, since the industrial company wants to gain more knowledge for commercial use. This will again create more common knowledge both for the industry and the university. Some of the students also receive a job offer after they have completed their master thesis project in the industrial company, and the relationship between the university and the industry is strengthened.

4 SUMMARY

The university-industry collaboration for the master thesis has developed over the years, but there is still a large potential for improvement, both in terms of standardization of the processes and in the other end adaption to the individual companies and the unique students. Working with industry ~~is~~ demands a wider set of both competence and skills than a traditional master thesis.

The learning outcomes for both the university and the industrial companies are exciting and can be developed in many directions. The knowledge triangle can be support by this university industry collaboration, and be further developed with many different tools; research projects, lifelong learning concepts, exchange of staff and industry internship of students.

Future research will be related to a more detailed description and elaboration of the concept, both from the perspective of pedagogy and the knowledge triangle.

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