On Supervising Master's Theses in Industry Context

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ABSTRACT

In software engineering, students easily find internships in companies while still studying. To combine their studies and employment, many of them seek to compose their final theses in an industry context, for the benefit of the employer as well as to simplify their context switching between job and studies. This can put the student between a rock and a hard place, as on one hand the employer has certain expectations in terms of working for the company, whereas the supervising professor needs to follow the university guidelines. An additional aspect worth considering is the university as an administrative home for the thesis and owner of the thesis process. In this paper, we study how the different stakeholders – the student, the supervising professor, and the company – should act for the best possible results, so that the company problem gets solved, and the results can be reported in accordance with the best academic practices. The research builds on authors' collective supervision experience, covering more than 1000 theses (mainly master's level) and close to a sum of hundred years. The thesis has been mainly supervised in two universities, with the clear majority executed in this setup, but there are also several exceptions where the thesis has been eventually accepted in some other university. The results are expressed in the form of anti-patterns, which consist of a definition of symptoms of a problem, its root causes, and proposals to salvage the situation in a practical fashion.

CCS CONCEPTS

• **Software and its engineering**;

KEYWORDS

Software engineering education, industry-academy collaboration, thesis supervision

ACM Reference Format:
Hannu Jaakkola, Tommi Mikkonen, and Kari Systä. 2022. On Supervising Master's Theses in Industry Context. In *Koli Calling '22: 22nd Koli Calling International Conference on Computing Education Research (Koli 2022), November 17–20, 2022, Koli, Finland.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3564721.3564743

Koli 2022, November 17–20, 2022, Koli, Finland

ACM ISBN 978-1-4503-9616-5/22/11.
https://doi.org/10.1145/3564721.3564743

1 INTRODUCTION

Today, we are facing a global shortage in the competent labor force in software engineering. Consequently, many of the students in the field of software engineering find internships in companies while still studying, thus helping in salvaging the shortage and at the same time gaining valuable industry experience for the rest of their careers. To combine their studies and employment, many students seek to compose their theses in industry context. Often, this introduces benefits for the employer as well as simplifies context switching between job and studies. Due to these benefits making the master theses in industrial context have become very popular in Finland.

There are various industrial thesis setups. From the student's perspective, the best case is that the company employing the student provides working time for writing the thesis. However, this is rare in practice for various reasons. Typically in Finland seems to be that the employer provides the topic and time for empirical research, but the final reporting in the form of writing is not paid for. In some cases, the results of the research provide the company with real value, and hence the time invested in reporting the technical work, eventually resulting in the thesis, is compensated. In some cases, the company provides a topic or simply a problem statement, but no supervision or other support for the work.

With such variance, it is difficult to define a one size fits all solution for making and supervising a thesis in company context, although the university should provide uniform support for students. Moreover, as companies and universities have interests and expectations of their own in the process, there can be various complications in the process of composing the thesis. Often, these complications are case-dependent, involving the student, the employer, and the university that eventually accepts the thesis. However, there are recurring problems, like defining a research problem that is relevant to both company and university.

The goal of this paper is to provide practical support for industry and academic supervisors who face this setup. In addition, we wish to help the students to understand the special nature of their work, so that they can help the supervisors and instructors from different organizations to collaborate, especially if the stakeholders are not familiar with industry-academia theses. The results are presented in the form of supervision anti-patterns, each consisting of the definition, context, symptoms, analysis of its root causes, and a known recipe for solving it. In this paper we use the term "industry" and "company" to cover a variety of organizations employing software professionals. These cover public and private, small and large organizations, software companies and organizations supporting their core business with ICT, and product and consultancy companies, all of which we consider are opportunities for thesis work

outside the traditional university framework. The idea of using anti-patterns as a tool for systematic problem-solution documentation and experience transfer was first introduced by the authors in industry PhD Thesis context in [9]. In industry MSc thesis, the idea of using of anti-patterns was introduced shortly in [10]. This paper builds on the latter results, elaborates the background of the work, and extends the idea by covering details of all anti-patterns recognized. In addition, our approach is positioned compared to the other approaches found in the analysis of the related studies.

The research builds on authors' collective supervision experience of more than 1000 completed theses, with the clear majority executed in industry-academia collaboration. Most of the thesis are at master's level, which is the usual level to enter the labor market in Finland, although some bachelor and doctoral theses are included in the data set as well. In terms of the time span, the theses have been supervised during 1990-2021, and the cumulative history of supervision of the authors is close to a hundred years.

The rest of this work is structured as follows. In Section 2, we provide the necessary background of this work, including the description of the thesis process, and the roles of the student, company, and academic institution. In Section 3, we introduce the setup of this research. In Section 4, which forms the core of this paper, we list the identified anti-patterns. In Section 5, we provide an extended discussion regarding the findings, give practical recommendations, and propose directions for future work. Finally, in Section 6, we draw some final conclusions.

2 BACKGROUND AND MOTIVATION

2.1 MSc Thesis as a Part of the Studies

The thesis is one of the last efforts of the MSc degree; mostly it is something left for the time after active study years. Majority, if not all, of the theoretical studies are already finished and the "mental mode" of the student is transferred from the role of full-time student to work and family life. The main difference comes from organizing the work. Scheduled classes and exams are changed to long term "research" oriented work, the project having a goal somewhere in the future of months ahead. Additional activities related to work and private life take up a growing part of the time. Students completing their theses are also often without an active supporting process.

The requirements of the MSc thesis are derived from University Act, which is applied by the university administration in varying ways. Every university provides the students with guidelines, which list the objectives, practices and processes related to the thesis and thesis process. Even the scope of the thesis may vary between universities – a short review shows the variation from 30 to 50 credit points.

Despite the guidelines above, more important than the scope of the thesis is the complexity of the study problem and its delimitation. It is not possible to convert directly into credit points. The thesis work takes the time it needs independently on the credit points reserved for is a part of the degree; wide variation appears. Another measure related to the thesis is its length in pages, where the typical recommendation is somewhere between 50 and 100 pages.

All measures defined by the rules have problems in industry thesis context. The number of pages does not directly indicate the scope and difficulty of the contents and does not consider the non-visible part of the thesis work – solving the problem and building the involving artefact as a part of the total work. In Software Engineering a typical industry MSc thesis solves a practical problem in the form of software, system, or process artefact, or, when dealing with reasonably new technology, the thesis seeks the possibilities or the limits of the technology, often with a company use case in mind. A lot of the effort in such work is focused in developing the artefact, which remains either totally invisible or has just a few pages visibility in the literary MSc thesis, which finally is the main target of the assessment and grading. The requirements of the thesis, set – and often aso formalized – by the academic community, cover the following:

- The student is familiar with the field of science and can gather new insights, with the thesis topic as a part of it.
- The student has the skills to apply scientific knowledge and methods in the solving the study problem.
- The student has skills required for independent and demanding research work.
- The student has good communication and language skills and ability to apply it in literal form in the study field.

The university supports the student with academic guidance and varying manifestations. Commonly, a plan-driven approach is used to enforce the progress of the thesis, including a project plan, thematic workshops/seminars (e.g. research methods, literature survey, academic writing), and predefined communication practices between the student and other stakeholders.

The thesis is defined to follow the principles of scientific work. The role of the research method, academic writing principles, and the use of references play an important role. The thesis prepares the student to become a researcher and to act as a member of the scientific community. However, just a few students continue in a scientific career; most of them move (or continue) to the industry after graduation. Still, the ability to scientific problem solving and exact, precise presentation has wider importance than only in the scientific community. These abilities are needed also in practical work, to solve problems in a systematic way, and in producing good quality written reports and studies.

Thesis as a scientific work expects that the author follows the selected scientific methods. The use of research methods has two functions. They should guide the researcher in the proper performance of the work and allow validation of the results. However, only a few students can apply the methods in the right way and a careful support of the supervisor is required. If the student has not succeeded to bind the role of the method in the work in a fluent way, it gives the impression of quasi-science instead of providing evidence of a good scientific work. This leads to lower ranks in grading of the work. The role of explicit use of scientific methods in industry thesis is worth of further discussion, because most of the works apply the principles of (a variety of) constructive research methods – i.e., rational problem solving – even without visible use of the formal methods.

The following roles relevant to the thesis project can be summarized from the above discussion: (1) university (administration), (2) student and (3) supervisor (professor). In the industry thesis the fourth stakeholder, the (4) company (and its representative as an

instructor), enters the process in a key role. The company is represented by the instructor having responsibility to bring the company needs to the thesis work. These roles, their responsibilities and collaboration are widely discussed both in the related studies (see sub-section 3.2) and in our analysis.

There are differences in the cultures between universities (and sciences) in the acceptance of the industry-oriented approach in a thesis. We have also found a big variation between companies in their readiness to handle the thesis work and in being a part of such joint activity with a university. The role of the supervisor is important in guiding the student through the "long term" "research project". The readiness of professors to supervise (and accept) a non-typical, industry-oriented work varies a lot, too. Variation between students in their readiness for a industrial thesis is naturally big, too. To summarize, the readiness of all counterparts of the industry thesis is varying. The term "readiness" would also be replaced by the concept "maturity", which is commonly known in software engineering contexts. This aspect is handled in the analysis and discussion of our paper, too.

2.2 Related studies

To position our study on the existing body of knowledge in the area we conducted a "light" literature study following freely the principles of the mapping study introduced in [12, 15]. The Step 1 (Definition of Research Questions to define the Review Scope of the study) is handled in Section 3 of this paper. The Search (Step 2) was conducted (only) in Google Scholar using the search phrase "master's thesis in industry" and some of its variants. The search found close to one Million papers having a wide variety of perspectives to the topic. One of the authors conducted Step 3 (Screening of papers) manually by reviewing the paper titles until penetration (no new approaches found). Based on the screening, the papers were mostly reporting findings in academia-industry collaboration and transfer of knowledge from university to industry, which was not in our interest. As a result of title-based Screening 54 papers were selected to the Step 4 (Keywording using abstracts). It left us nine papers found essential from our work point of view classified in three categories. The Step 5 of the mapping study (Data Extraction and Mapping Process) was not conducted, because it was not needed to fill our goal to position our approach to others.

Industry MSc thesis was directly discussed in five papers. Höst et al. in [8] report the Swedish experiences in the thesis projects conducted as a co-operation between a university and industry. The study is based on interviews of students and supervisors in three universities to explore the problems that the different stakeholders have during thesis work and to investigate the need for support. The paper defines a support model to outline the types of support needed. The author remains the details of the model outside this article and confines himself to a general examination of it. The model includes both general thesis guidelines and guidelines for the actual thesis project. The projects are assumed to be constructive, either as evolution of an old or as creation a new artifact, method, or process. The proposed model seems to be tuned to the characteristics of the thesis project and its interest groups in many dimensions, which makes the model context sensitive and complex to publish as documentation.

Knauss [13] analyzes the key factors of conducting a master's thesis in industry. The work requires seamless collaboration between stakeholders from academia and industry. The difficulty to combine the goals of empirical (practical) work and academic quality easily leads to compromising either one. Implementing the work within the typical time frame (scope) reserved for the thesis is difficult. Although constructive research methods, especially Design Science Research (DSR), is applicable in applied research, limited experience exists to apply it within the context of a master's thesis. The paper lists six DSR guidelines (based on definition of DSR [7]) are listed and commented to consider the special needs of industry thesis. The paper has analyzed twelve MSc thesis covering the period 2014-2020. Based on the analyses it lists typical pitfalls and good practices recognized and aspects related to the interaction between different counterparts. The results of the analyses generated seven practical guidelines for conducting master's thesis in industry guided by the DSR method; as solutions to the problems recognized it has similarity to our work. The paper itself follows the principles of DSR and provides good examples about its application.

Järvinen and Mikkonen [11] provide a view to the topic selection for industry theses. It is based on the analysis of 578 thesis on software engineering in the period of 1990-2016 in Finland and reports changes in the selected characteristics: company size, type of the project (independent / part of bigger project), research / practice orientation, language of the thesis, topic area and gender of the student. The golden role Nokia in early 2000 was visible in the trends. The paper creates an interesting perspective on the industry thesis trends but has not handled the thesis process and its challenges.

In [14], Morris et al. point out the rising role of university-industry research collaboration; the study context is Australia. It assesses the impact of a student's experience in a university-industry research project compared to a pure academic project. The recognized main difference is supervision by two different supervising roles in the industry thesis compared with typically one in academia. The paper investigates the differences of these two supervision types from the point of view of supervision itself, institutional access, and engagement.

In [17], Tomás et al. handle the slow progress of master theses in a Portuguese university: less than half of the students complete their work in the planned time frame. The authors have developed a Scrum based framework to supervise the thesis. The reported experiences are promising; the methods derived from Scrum are applicable in thesis supervision and solve some typical problems in thesis projects. This paper provides an interesting solution to the problem of non-successful thesis projects. While directly not associated with industry theses, we believe that a similar framing could be introduced to help industry masters' students advance in a more controlled fashion. Furthermore, such a well-defined process supports collaboration between different stakeholders

Two of the papers handled the industry-academia collaboration in education. The paper [19] of Wohlin and Regnell includes discussion about making software engineering education relevant from industry point of view and how to give the students good skills for large-scale software development in industry. The approach covers both education and research at graduate and postgraduate level. Based on the analysis of university curricula, the paper lists a

collection of important aspects and tested strategies for industrial relevance in software engineering education. The strategies focus on practices to combine the work with studies, combining research and education, incorporating knowledge of industry practices into teaching, and organizing courses to provide skills in practical software engineering work. The paper proposes also to start a special postgraduate programme for students from industry.

Software engineering education needs elements providing students an ability to apply their skills in a practical environment that resemble real-world. Small software projects are implemented by small teams following the principles of real-world software projects. Broman et al. in [2] criticize such "capstone courses" about the limited perspective to the problems of the real industry environments. The paper introduces an alternative approach, called the "company approach", having a more realistic approach in organizational, process, and communication related problems of project work. Practical guidelines are given for learning outcomes, teaching and learning activities, assessment, and course implementation practices. In the course implementation the students are not organized in teams but in simulated companies (size appr. 30 students) organized by the students and consisting of several collaborating teams. The implementation of the course has been tested in practice and its functionality tested by conducting a survey of students. The results support the success of the approach introduced.

Two papers focus on general aspects in industry-academia collaboration. The role of industry-academia collaboration is handled by Wohlin et al. in [18]. The paper points out the importance of such collaboration from two view points: first it transfers innovations to industry, secondly it ensures the industrial relevance of the academic activities. The findings reported are based on two surveys, one in Sweden and one in Australia. Results between two selected countries do not vary significantly. The key factors found are the needed support from company management, the role of "collaboration champion" in the company, and the researcher's attitude, commitment and social skills. Collaboration champion is a kind of "collaboration process owner" in the company having responsibility to progress the work in practice. This role is quite similar to the industry instructor of the thesis, which we found to be one of the key factors in the case of an industry thesis. The problems related to the collaboration between organizations is handled by Sannö et al. in [16]. The different expectations and views are sources of difficulties. The paper analyses the key factors of collaboration based on the study conducted as action research in six research cases. The management of different phases in such co-production were reported as a key factor of success as well as combining practical relevance to scientific rigor.

To conclude, the papers discussed above support our findings in the problems of thesis work and industry-academia collaboration. Compared to our work the papers are focused on small case material and report the results of focused aspects in the thesis in industry thesis related problems.

3 RESEARCH SETUP

3.1 Research questions, data, and methods

In this paper, we seek to understand how to better supervise students who work in the industry but are in parallel composing their theses. The exact research questions are as follows:

RQ1: What problems are recurring in the supervision of theses composed in industry, based on industry topic?
RQ2: What are the symptoms of these problems that make the problems actionable?
RQ3: What actions can be taken to rescue the situation?

The research process started by every author collecting typical problems from his/her own dataset, that is, the theses they have supervised. Altogether, the authors have supervised more than 1000 theses of various type, many of which have involved company collaboration. In addition, there is also a large number of theses that have never been finalized, which also contribute to the problems identified in the paper. The typical problems identified by the authors were then elaborated in a number of workshops among all the authors who collaboratively did root cause analysis for the different theses and the authoring student. The saturation point was reached when a workshop produced no more common problems. At this point, the authors started to document the problems in a joint spreadsheet.

Upon listing the problems were listed we performed an analysis, where symptoms and the different causes of the problems were recorded, by one of the authors. The analysis was then validated and extended by the rest of the authors. Next, the authors collectively considered how the situation could be salvaged, based on real-life cases where the proposed solution had worked. In addition, the enabling conditions for salvaging the problems were analyzed.

Finally, all this data was organized as anti-patterns that describe a problem that emerges in a certain context, and possible ways to overcome the problem, following the anti-pattern format that has been used to report other cases where an erroneous behavior or solution has been fixed, producing a working solution as the outcome [9, 10]. In total, we recognized more than 20 sources of problems for further analysis. These were ordered based on their importance and prevalence and classified in three categories based on the source of the problem: topic issues, resourcing issues, and communication / collaboration issues. Some problems indicated the same phenomenon; these were merged under the more general title. There were also general topics that did not specifically relate to industry theses. These were excluded from the list. Eleven problems were selected for more detailed processing.

3.2 Anti-patterns – a systematic approach to the problems encountered

The idea to use a structured approach in the form of patterns is adopted from software design practices. Design patterns [5] are representatives of good design solutions and reflect positive quality properties in software architecture. In contrast, anti-patterns are representatives of bad quality solutions having problems or obstacles in the context it occurs [3]. Recognizing the existence of anti-patterns triggers corrective actions to avoid the related problems. An essential factor in the use of a pattern-based approach in software design is the opportunity to recognize the problem and implement the solution provided by the pattern in the form of structured documentation.

Here we apply the similar structured approach for analyzing the issues for making theses in an industrial context, following the example set by [9, 10]. While the thesis pattern would represent a

good solution, the thesis anti-pattern describes problems related to the work. Corrective actions transfer the work towards a good solution. The systematic documentation structure points out the essential elements needed to recognize and understand the problem, allows to find its root cause and further to find corrective actions either to avoid the problem in advance or minimize its negative effects in the thesis process. The (anti-)pattern structure includes the following components:

- **Name of the anti-pattern**: Unique name used to identify the anti-pattern.
- **Context**: A context or situation giving the background to a problem.
- **Problem**: Description of the problem handled by the pattern.
- **Symptoms**: How this problem is seen in practice, manifestation of the problem.
- **Corrective actions**: How to fix / avoid the situation (if possible), corrective actions.
- **Notes**: Other notes related to the situation.

In the following section, we will report the anti-patterns, which we have found typical for industry MSc thesis; the findings are based on our long and reasonably wide experience in the role of supervisor in our universities. We believe that the ideas introduced are applicable and reusable (for all counterparts) elsewhere as guidance to proceed beyond the obstacles documented by the anti-patterns. However, it should be recognized that the presented anti-pattern list is by no means complete. Rather, it is simply a collection of recognized, recurring situations that the authors have been experienced.

4 ANTI-PATTERNS OF INDUSTRY MSC THESIS

4.1 Topic Issues

The first category of problems we address has its roots in the topic of the thesis. The selected topic should be suitable for an industrial master thesis and fulfill the following criteria:

- The company should have a genuine interest in the topic and results.
- The topic should be suitable for an academic thesis. There should be some prior art and related research and the results should have elements of general interest. This does not, however, exclude constructive and implementation-related topics as a thesis topic.
- The topic should be suitable for the interest and competence profile of the student.
- The academic supervisor should have sufficient interest and knowledge. However, it is not expected that the thesis directly matches the supervisor's research.

These aspects relate in the abilities of the student, the interest of the supervisor in the topic area and company's expectations.

Not a company project: The student is recommended to seek a thesis topic in the company context, so that the thesis would be a part of the company's interests. However, many students work in a subcontracting mode in consultancy companies where software is developed to serve direct interests of another (customer) company. Even if the work would be a good match for a thesis, the topic may not be used as a thesis, because the customer of the project is against that.

- **Name of the anti-pattern**: Not a company's project.
- **Context**: Many young professionals work in consultancy companies where the projects are owned by the customers. Companies may have little to say regarding a thesis topic, if a customer is buying consultancy and the company acts as a subcontractor only.
- **Problem**: The thesis is not of the interest of the owner of the project. Customer is afraid that they need to pay for the thesis writing.
- **Symptoms**: Slow process.
- **Corrective actions**: Form a clear, explicit agreement between stakeholders. Use internal development topics instead of customer projects.
- **Notes**: Internal development topics are possible if the company has common processes or technologies.

Too short projects: The student participates in short projects, often allocated to them on a short-term and unpredictable basis. This results in participating in small tasks instead of a bigger whole. Typically, none of the tasks is well suited to be used as a thesis topic, which is then pushed further ahead one day at a time.

- **Name of the anti-pattern**: Too short projects.
- **Context**: Tasks change so frequently that there is no time to compose a thesis. This is common in the consultancy companies where the student is often allocated to new projects frequently.
- **Problem**: There is no way to intimately connect the work and thesis.
- **Symptoms**: The ongoing research stops, or the student proposes change in the topic.
- **Corrective actions**: Use internal development topics instead of the customer projects.

Irrelevant topic. The company acknowledges the student's will to compose the thesis while working for the company. To support the student, the company finds a topic that is well suited for a thesis, but not directly associated with company interests, so that there will be no conflict with respect to company work. In the worst case, the topic is so esoteric that even the university supervisor is unable to follow the rationale.

- **Name of the anti-pattern**: Irrelevant topic.
- **Context**: The company has a good will and helps the student to find a topic. However, the company has no real interest on the topic.
- **Problem**: The company's interest to support the thesis is limited.
- **Symptoms**: Interest-level of the student is reduced since the company is unable to provide clear context and domain insight for the work.
- **Corrective actions**: The university supervisor talks with the company to find out what is the motivation. Possibly the stakeholders can find a new angle that is more relevant for the company or that connects the work to some research done at the university. Sometimes it is better to change the topic to something that relates to university's research interests.

Topic selection ignorance: Even if the employing company has good will to support the student, and they would like to help the student to compose the thesis, they have no experience in selecting a topic that would be fit in size and relevance for a thesis.

- **Name of the anti-pattern**: Topic selection ignorance.
- **Context**: Even when the company has projects that would be good fit for thesis work, the student and company instructors are unable to detect them.
- **Problem**: Lack of vision and experience to identify a suitable topic.
- **Symptoms**: Frustrated student as there is seemingly no theses to work on; frustrated company instructors who cannot help their employees.
- **Corrective actions**: University supervisor(s) openly communicates about possible topics; company can also collect candidate topics and already complemented thesis as samples.
- **Notes**: Use of the university supervisor's experience is important, and the supervisor should be open-minded enough and consider topics beyond his/her closest research interests.

4.2 Resourcing Issues

This subsection is dedicated to the problems of finding enough time and other resources for the thesis in the middle of other company operations. Overall, the full work-life balance should be considered here, as responsibilities that compete with the work and the studies reduces the resources.

Ability to re-use the results of the daily work in the thesis increases resources. So, it is also important that the other stakeholders – especially the company – provide resources for the work. It is not a good idea, neither from the company or from a student point of view, to force the thesis related work to be conducted as a "slave" work using student's private time. One important aspect of resourcing is a need for stability (in work and private life) for the time of making the thesis. Keeping the focus on the chosen plan is an important part of this stability.

Company priority: At times, thesis topics are on a critical path of company interests. While seemingly a good thing, as this guarantees company interest in a topic, the downside is that often company interest takes over and there is no time to write thesis until immediate company interests have been served.

- **Name of the anti-pattern**: Company priority.
- **Context**: There is a company project that is well suited for a thesis, but it is also in a critical path for the company.
- **Problem**: Company's business critical part of the project takes all the effort, and the student never gets time to finalize the thesis.
- **Symptoms**: The thesis is not progressing despite the technical contributions. Student (possibly) and university supervisor become frustrated.
- **Corrective actions**: A plan is made where the student gets time to complete the thesis after the project.
- **Notes**: This is often amplified by the excitement of the student; work on the business-critical part is often more interesting than writing of the thesis.

No commitment: Companies often have numerous potential topics for theses in their agenda. However, if several topics are proposed to a student at the same time, it will be difficult to commit to one of those. Moreover, chances are that, after picking one thesis topic that seems interesting and relevant, there will be an option to pick another, even more interesting and relevant topic. This can form a vicious circle where the student cherry-picks topics but never makes progress on any of them.

- **Name of the anti-pattern**: No commitment.
- **Context**: Even when a company has projects that would be good fit for thesis work, the student may be undecided to selecting one.
- **Problem**: Inability to commit to a topic and there is a constant shift in the direction. This problem can also originate from supervisor and instructor.
- **Symptoms**: A frustrated student as there is seemingly no theses to work on; a frustrated company instructor who cannot help their employees.
- **Corrective actions**: Supervisor and instructor are introduced to each other; together they help the student to select a suitable topic and research angle. Students should also help to stick to it.
- **Notes**: This is also a topic issue.

Lonely wolf: The student is hired in a company that is not really a software engineering company. Over time, she has become the sole expert in the field in the company context, and there is no way the rest of the company could provide real help for the thesis. Sometimes this happens also so that the student is the only expert in a certain domain of software development.

- **Name of the anti-pattern**: Lonely wolf.
- **Context**: The student is the only expert of the area in the company
- **Problem**: Student do not get discussion partners.
- **Symptoms**: Lacking support leads to slow progress.
- **Corrective actions**: Increase support by university supervisor; select topic with domain interest, try to find a bigger research frame within other organization than the company.

Overloaded student: A number of companies in Finland rely on students in their core businesses, and the students do not play only a supporting role. Hence, when the situation gets hectic in a company, the students are also harnessed to serve the company goals instead of their personal ones. Hence, it is common that the student puts aside the thesis and puts the company interests at the top of her priority list. This in turn can lead to delays in thesis work.

- **Name of the anti-pattern**: Overloaded student.
- **Context**: Company has lack of resources.
- **Problem**: The student needs to work hard - often overtime – already in daily company challenges.
- **Symptoms**: Thesis does not progress. The work-related tasks take precedence over it.
- **Corrective actions**: Aim at a solution, in which predefined time, e.g., one day in a week is reserved for the thesis work. This needs support from the supervisor side. Sometimes, the only solution for the student is to change the company.

- **Notes**: This usually an indication of bigger problems in the company.

Cancelled project: The company project behind the thesis topic is interrupted. Numerous reasons – often good ones – exist, such as the student changes the company, the company moves resources (student included) reserved for the project to other activities, the interest of the company to the project ends, solution to the problem is found from other sources, and so on. In all cases, from the student point of view, the situation is the same – there is a major disruption, and the work done for the thesis so far is in danger of not being exploited, and hence the thesis is not completed.

- **Name of the anti-pattern**: Cancelled project.
- **Context**: Project related to the thesis is cancelled or otherwise seriously disrupted.
- **Problem**: The topic may become obsolete; no access to empiric data after leaving the company. No time provided to continue the project.
- **Symptoms**: Old topic becomes irrelevant; the student starts to contact supervisors to check if a new topic should be identified.
- **Corrective actions**: Supervisors should check together with the student if the already implemented piece of work can be framed as the thesis by narrowing the research questions or by refocusing the key contributions. Often, this results in devaluating the thesis, but it is still possible to complete thesis, if the student accepts to lower her ambition.
- **Notes**: If the topic seems risky, the supervisors may check and warn in the beginning of the process.

4.3 Communication and Collaboration Issues

This subsection addresses communication issues related to the student, company/organization and university, and the two supervising roles, university supervisor and industry instructor. Obviously, all of them should have compatible interests, but at the same time, in addition to taking care of their own interests, they all should acknowledge each other's interest, and be able to collaborate efficiently to meet the joint goal.

Wall between supervisors: As companies and industry do not automatically meet to discuss their common interests, it is common that the industry instructors and university supervisors do not know each other. Even worse, they may not ever discuss with each other regarding the thesis which can introduce conflicts in the expectations. This potentially results in conflicting messages in the supervision process.

- **Name of the anti-pattern**: Wall between supervisors.
- **Context**: Company nominates its own instructor, but there is no collaboration with the university supervisors.
- **Problem**: Company instructor and university supervisor(s) give conflicting instructions and advice.
- **Symptoms**: Confused student, supervisors get confused.
- **Corrective actions**: Supervisors and instructors are introduced to each other, and they agree on roles in the beginning and communicate regularly.

IPR boundaries: In companies where products and IPR play a major role, it is not uncommon that the students need to understand which information is confidential, and what is open to the public. In the worst case, the company instructor is also uncertain about this issue. The outcome is that it is very difficult for the student to decide what information to reveal in the thesis and what must remain confidential. Finally, it should be noted that there have been cases where IPR related issues were used by the students to artificially pump the importance of the research in company terms.

- **Name of the anti-pattern**: IPR boundaries.
- **Context**: It is often unclear what is company confidential information and what is not, in particular, when student works part time in a bigger company project.
- **Problem**: Students do not know what they are allowed to write or even talk about with the thesis supervisor.
- **Symptoms**: Confused student, supervisors become confused.
- **Corrective actions**: Clear and explicit agreement between all stakeholders. Explicit discussion regarding what is confidential information and what can be shared. University supervisors can be given special privileges to help in the process and to improve.
- **Notes**: Sometimes the issue is related to topic selection if there is not enough public material. Usually, the problem is related to lack of discussion and understanding leading to protecting too much.

5 DISCUSSION

It is well-known that there are numerous hurdles that can lead to problems while composing a thesis, such as having to work independently, to be able to discover essentials and to engage in critical thinking [6, 46–47], or becoming producers of knowledge instead of consuming it [1, 58–60]. However, when we started to drill down to problems that emerge in industry theses only, it turned out that the anti-patterns were not that many. Obviously, common problems that one can encounter while composing a thesis are relevant to industry theses as well. Here we have overlooked them and focused on those that by necessity require the industry context, in addition to the purely academic one.

One interesting note in the analysis of the anti-patterns was that consultancy companies are more challenging than product companies. The difference between these two company types is in their role in the development activity: where product companies develop products for themselves or on behalf of the end customer, consulting companies act as service providers, intermediaries and experts in various types of development projects.

The most important means to prevent or correct the problems appear to be communication between all the stakeholders especially in the early phases of the process. With good communication and collaboration problems related to topic selection and resourcing can be mitigated. However, experience increases readiness in such collaborative activities: the more experience the partners have with the industry-academia cooperation, the more natural the cooperation will be. This fits, of course, to the industry and the academic partner. The positive factor is that the instructor has conducted his/her thesis in a similar context having experience from a student perspective. Differences in educational attainment between the partners may be a problem, although not necessarily.

In general, based on the experiences that have inspired this work, we cannot emphasize enough the trusting and confidential nature of collaboration between the instructor and supervisor. Jointly, they bear a great responsibility for the successful implementation of the thesis process. Therefore, any problems in their collaboration may appear confusing to the student, who can then be framed in between the rock and the hard place. To avoid such problems, setting up personal relations among the supervisors is a low-hanging fruit for a successful thesis process. At times, it has happened to the authors that the company instructor is a former student of an author, in which case the process is clear immediately for both sides. As such cases are rare, it is recommended that the university side is prepared to provide instructions for the industry stakeholders – after all, this might be the only thesis that the company supervises, whereas professors who are working with industry theses will face the situation constantly. In exchange, the university supervisor needs to be prepared to understand the company situation and viewpoint, which seldom takes only the thesis into account. At best, this can also help companies and universities build more insightful relations with respect to other joint activities.

A key limitation of this work is that the results are clearly context-dependent, and the same patterns may not be globally applicable. The underlying assumptions are embedded in societal context and industry-academia collaboration, where students become employed by companies before they graduate, which is not the case in every country. However, internships are common in software engineering on a global scale, and hence we trust that the learnings will bear significance outside the national setup. In fact, we encourage others to study the same phenomenon with respect to their industry-academia collaboration, to see if related problems emerge, thus supporting the whole software engineering community in general and the students who are about to join it in particular. Another limitation of the work is the time span during which the studied theses have been composed, which is 25 years. The analysis was done with the present situation and authors' experience in mind. However, the journey to this point has had a major effect on the considerations that have motivated the work and are documented in the patterns. Hence, it is possible that if a similar analysis were done at another time, the observations would have been different. To compensate for this weakness, we have done our best to consider the issues through the lenses of the context at the time of composing the thesis, not the present-day situation.

We found the mapping study of the related papers (Section 3.2) interesting. The approach in the prior work, on the one hand, is different from our approach, but on the other hand, they support our observations on the factors contributing to success and failure in industry thesis context. Especially the guidelines of Knauss [13], in spite of having their starting point in the correct application of the research method, proved to focus partially on similar problems as we handle in our anti-patterns, and solutions to them; these could also be transformed and further handled in the form of additional anti-patterns. Candidates for such anti-patters are presented in boldface text in the text below. Below we quote shortly these guidelines Knauss (in italics) and comment on these:

G1: "*Define the artifact early. Use it to agree with all stakeholders on the thesis goals with respect to knowledge contribution*". This is related to a lack of communication and a poorly defined project. There would also be a breakpoint between the project and thesis. Thesis planning is post-mortem of already done work. **Incomplete definition** anti-pattern.

G2: "*Work in iterations. Improve the artifact and the knowledge in each iteration. Specifically, contribute to each research question in each iteration*". Unfortunately, the company cycles are dominating; sometimes these are not parallel with optimal research cycles. **Incompatible cycles** anti-pattern.

G3: "*Define research questions with respect to the regulative cycle, i.e. one related to the problem, one related to potential solutions and their construction, and one related to evaluation (match solution to problem).*" A well applicable principle, which does not lend itself to a formulation as an anti-pattern.

G4: "*Have regular meetings. Student and supervisor meet once per phase (once per week). Student, industry supervisor, and academic supervisor meet once per cycle (once per month). Goal: support rigor.*" Sounds to be good practice. However, meetings between company supervisor and student should have a higher meeting frequency. The reasons for not meeting can reflect a number of anti-patterns listed above.

G5: "*Shift emphasis between cycles. Work on each research question in each cycle, but put more emphasis on RQ1 (Problem) in Cycle one, on RQ2 (Solutions) in Cycle two, and on RQ3 (Evaluation) in Cycle three.*" This is typical in a phase/cycle based approach. In practice thesis related cycles are more complicated, because practical work should progress hand in hand with literal work, parallel or sequentially. **Cycle breakage** anti-pattern.

G6: "*Have a dedicated section to describe the artifact. A concise description of the artifact is beneficial to the casual reader and allows other sections (e.g. findings, discussion) to focus on the learning, not the artifact.*" Sometimes this is not a problem. The problem instead is focusing on irrelevant things. The source of such would also be a slavish clinging to the research method. **Method slave** anti-pattern.

G7: "*Write the thesis document as you go, but do not submit it that way. Often, the best way to report your results can only be decided after Cycle 3. Thus, chose the least obstructive way of documenting the results during the thesis (chronological). Then restructure before submission.*" Too often it happens that the work is too long hidden from the supervisor and opportunity to failed approach has continued too long. **Hidden results** anti-pattern.

The anti-pattern proposals outlined above are more general rather than industry specific. However, by highlighting them, we wanted to show that the anti-pattern approach is possible to generalize and widely applicable in different situations. Höst et al. in [7] summarize good industry thesis practices as a multidimensional support model, which can be compared to a detailed thesis instructions manual. Some similarities to our work can be found in it, too. The "industry approach" by Broman et al. in [2] describes a model that is reminiscent of our approach in the industry thesis context. The rest of the studies point out the importance of seamless collaboration between different the interest groups, as well as the need for efforts to increase understanding of the expectations of

industry in the early phase of the university studies. The role of university as a source of innovations to be transferred in industry is also recognized. Our approach in solving thesis (work) related problems has wide coverage of experiences from practice. It is analytical and solution-oriented. It extends the problem base found in earlier studies. The anti-pattern is easy to apply by new users to improve the quality of thesis processes in universities globally.

Finally, we acknowledge that to succeed in composing industry theses requires certain maturity and broad mind from all the involved parties. To address this, the patterns as such, while helpful at day-to-day level, are too simplistic a way to understand the problems related to thesis supervision in industry context. Clearly, there are differences in the view that the universities have on industry theses, ranging from overlooking them almost completely to embracing them as a way to employment for students. Similarly, depending on how familiar companies are in working with universities, theses done on company topics can be regarded either as something that is almost a nuisance for a company, to be offered only if they have to, to something that is a vehicle to advance the company's direct interests. Therefore, while the anti-patterns proposed above reveal problems and offer a way forward, we believe that more thorough investigation requires a model that considers the maturity of collaboration from both company and university perspective covering all interest groups. Such maturity could then be used to organize the patterns in the form of a pattern language or, even more ambitiously, as an established maturity model like CMMI [4]. This can be used to analyse and understand the problems and the solutions that are within the reach of the different stakeholders. This is a topic for future research.

6 CONCLUSIONS

In this paper, we have reported eleven anti-patterns in three categories: topic-selection related problems, resourcing problems and collaboration issues. The most common way to solve the issue is utilization of the supervisor's experience in topic selection and planning of the research. However, it needs experience, which grows only in the way of supervising the growing amount of thesis, along with the work experience. The setup of our study listed three research questions to guide our study. These have found a solution in the following way:

- RQ1: What problems are recurring in the supervision of theses composed in industry, based on industry topic? The problems are listed in our anti-patterns, as well as in the analysis of the related studies.
- RQ2: What are the symptoms of these problems that make the problems actionable? These are included in our anti-pattern analysis to provide a starting point to solve / avoid the problem encountered.
- RQ3: What actions can be taken to rescue the situation? Even these are included in our anti-pattern presentation. The analysis has been supplemented in the discussion section of the article.

To conduct the thesis in industry is beneficial for all interest groups related to it. The student gets a good start for his/her career, the company gets new talent and gets new insight from scientifically sound research. The professors get insight from actual problems in the industry and can use that in steering the research and education. The industrial theses have some typical difficulties, which might be avoided in non-industrial ones. Based on our long experiences we have formulated the typical problems in a form of eleven anti-patterns. For each anti-pattern we propose ways to prevent and mitigate the problem. We propose that these findings are used to form a model for new universities and companies to adopt and mature in the practice industrial master thesis.

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