Practices for Supervising Master's Theses in Company Context: An Anti-Pattern Approach

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Abstract - **Software Engineering (SE) university students often work part-time during their studies. In this setup the students can reform the practices of companies by transferring what they have learned to companies and correspondingly utilize what they have experienced at work in their studies. This symbiosis often continues as the students begin to work towards their thesis. The topic of the thesis relates to the problems in the company. These topics often solve a practical problem, which are not always in a perfect match with academic expectations. On the one hand the employer has certain expectations in terms of working for the company, whereas the supervising professor needs to follow the university guidelines. In this paper, we study this tension by focusing on the problems appearing in MSc thesis process in company context. We propose ways to act so that the different stakeholders -- the student, the professor, and the company -- reach the best possible results. We have analyzed the problems and their root causes. We have also taken the first steps toward anti-patterns for analysis and salvaging of the problems. The study is based on the authors' collective supervision experience, which covers over 1000 MSc theses, with the combined supervision experience of over 100 years.**

Keywords - Software engineering education, industry-academy collaboration, thesis supervision

I. Introduction

There is a global shortage for a competent labor force in software engineering. Consequently, the students 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. In the best case, 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 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, product and consultancy companies.

There are various setups for an industrial thesis. From the student's perspective, the optimal case is that the company employing the student provides working time for writing the thesis. However, this is rare in practice for various reasons. The norm in Finland, where our experiences is from, 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. Finally, in some cases, the company provides a topic -- sometimes only 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. As the companies and universities have interests and expectations of their own in the process, there can be various complications in the thesis process. Often, these complications are case-dependent, involving the student, the employer, and the university that eventually accepts the thesis. Sometimes the problems are recurring, for instance, 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 the above 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. We have found important to find means for *systematic documentation* of the situations we have found problematic in industry theses. The aim is to provide a useful tool to transfer experiences between organizations and stakeholders. The results will be presented in a form of *anti-patterns*, each consisting of the definition, context, symptoms, analysis of its root causes, and a known recipe for solving it.

The research builds on authors' collective supervision experience of more than 1000 theses, with the clear majority executed in industry-academia collaboration in Finland. Most of the theses are at master's level, which is the expected level in Finland to enter the labor market, but some bachelor and doctoral theses are included 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 over a hundred years. The theses have been mainly supervised in two universities, which

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both have a long tradition in software engineering education.

The rest of this work is structured as follows. In Section II, 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 III, we introduce the research setup. In Section IV, which forms the core of this paper, we list the identified problems and the anti-pattern concept. Section V covers discussion and some final conclusions.

II. MSc Thesis as a part of the studies

The thesis is one of the last efforts of the MSc degree. 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 thesis are also often without daily support.

Every university provides the students with guidelines for the objectives, practices and processes related to the thesis and thesis process. The approach is a *plan-driven* one to guarantee the progress of the thesis, including "project plan", thematic seminars (e.g. research methods, literature survey, academic writing), and predefined communication practices between the student and other counterparts.

The manifestation of the success of the thesis process is the written document. In Software Engineering a typical industry MSc thesis solves a practical problem in the form of software, system, process artefact, or assessment of the feasibility of new technologies. A lot of the effort in such work is focused in developing the artefact, which remains either invisible or has just a few pages visibility in the literary MSc thesis, which finally is the main target of the assessment and grading.

In addition to the practical (constructive) goals the thesis primarily must follow the *principles of scientific work*. The role of the *research method*, academic writing principles, and the use of references play an important role. Thesis as a scientific work expects the author to follow the selected scientific methods. How explicit and visible the research method should be in the thesis varies. 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 succeed 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. Although the ability to scientific problem solving and literal presentation prepares the student primarily for an academic career, these abilities are needed also in practical work, to solve problems in a rational way, and in producing good quality written reports and studies.

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 counterpart, the (4) *company* (and its representative as an *instructor*), becomes in the 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 (sub-section III.A) and in our analysis.

There are differences in the *cultures* between universities 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 participating 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) an 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 stakeholders varies. The term "readiness" would also be replaced by the concept "*maturity*", which is commonly known in software engineering contexts.

III. The key elements of our approach

A. Related Studies

To position our study on the existing body of knowledge in the area we conducted a simple *mapping study* [10; 13] in Google Scholar using the search phrase "master's thesis in industry" and some of its variations. A huge amount (thousands) of papers were found by the search handling the topic area from a wide variety of perspectives. The papers that were closely related to this paper, were mostly reporting findings in academia-industry collaboration and transfer of knowledge from university to industry. Following the systematic mapping study principles, by filtering the findings and focusing on the essential papers from our work point of view we selected nine papers having contributions relevant to us.

Industry MSc thesis was directly discussed in five papers. Höst et al. in [7] report the Swedish experiences in the thesis projects conducted as a co-operation between a university and industry. The paper defines a *support model* to outline the types of support needed. Knauss [11] analyzes the key factors of conducting a master's thesis in industry. The difficulty to combine the goals of empirical (practical) work and academic quality (research methods) easily leads to compromising either one. 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 to consider the special needs of industry thesis. Järvinen and Mikkonen [9] handle the topic selection for industry theses. It is based on the analysis of 578 theses on software engineering in the period of 1990-2016 and reports changes and trends in the selected characteristics. In [12] Morris et al. point out the rising role of university-industry research collaboration. It assesses the impact of student's experience in university-industry research compared to a pure academic project and investigates the differences of these two supervision types. In [15] Tomás et al. handle the slow progress of master theses in a Portuguese university. The authors have

developed a SCRUM based framework to supervise the thesis to support collaboration between different stakeholders.

Two of the papers handled the *industry-academia collaboration in education*. The paper [16] of Wohlin and Regnell includes discussion about making software engineering education relevant to industry and how to give the students good skills for large-scale software development in industry. The paper lists a collection of important aspects and tested strategies for industrial relevance in software engineering education. Broman et al. in [3] criticize software engineering education about elements included to the curricula to provide students an opportunity to apply their skills in a practical environment that resemble real-world. Such "capstone courses" have 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.

Two papers focus on *general aspects in industry-academia collaboration*. The role of *industry-academia collaboration* is handled by Wohlin et al. in [17]. The paper points out the importance of such collaboration from two viewpoints: first it transfers innovations to industry, secondly it ensures the industrial relevance of the academic activities. A key factor found is the role of "*collaboration champion*" in the company; it is a kind of "collaboration process owner" with a responsibility to progress the work in practice. This role is comparable to the *industry instructor* of the industry thesis. The problems related to the collaboration between organizations is handled by Sannö et al. in [14]. The different expectations and views of the organizations are sources of difficulties. The paper proposes practices to manage such *co-production* and to *combine practical relevance to scientific rigor*.

The papers discussed above support our findings in the problems of theses 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 industry theses related problems. Our approach is introduced in the following.

B. Research Approach

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 collecting typical problems from the authors' datasets, that is, the theses they have supervised. These typical problems were then elaborated in a number of workshops among the Finnish authors. The saturation point was when a workshop produced no new common problems. At this point, the authors started to document the problems in a joint spreadsheet. After listing an analysis followed – the symptoms and the causes of the problems were recorded, by one of the authors. The results were then validated and extended by the rest of the Finnish authors. Next, the authors collectively considered how the situation could be salvaged, based on real-life cases where the proposed solution had worked. Finally, the problems encountered were classified (by one of the authors) in primary and secondary categories. The categories were then validated by the rest of the authors.

The results will be finally reported using the anti-pattern format which has been used to report other cases where an erroneous behavior or solution has been fixed, producing a working one as the outcome. This format is selected, because the authors have successfully used this approach in some contexts in software engineering [8].

IV. Anti-patterns of industry MSc thesis

A. Exploring the problems

More than 20 sources of problems were recognized 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 and introduced in the following sub-sections B to D.

B. 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 general interest. This may 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 adequate interest and knowledge, however, expecting 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.

The *topic issues* are listed in below:

Not a company project: The student is recommended to seek a thesis topic in the company context, so that thesis would be a part of the company's interests. However, many

students work in subcontracting mode in consultancy companies where custom software is developed to serve direct interests of a customer. 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.

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.

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 essence, this is like a university-defined thesis topic. In the worst case, the topic is so esoteric that even the university supervisor is unable to follow the rationale.

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.

C. Resourcing Issues

This subsection is dedicated to the problems related to 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 reduces the need for additional resources. Still, it is also important that the other stakeholders - especially the company – enable allocation of resources for the thesis 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.

The recognized *resourcing-related issues* are:

Company priority: At times, thesis topics are on a critical path of company interests. While this seems lile a 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.

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.

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, and the rest of the company could provide real help for the thesis. Sometimes the student is the only expert in a certain domain of software development.

Overloaded student: A number of companies in Finland rely on students in their core businesses. When the situation gets hectic in a company, the students also need 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.

Breaking project: The company project behind the thesis topic is interrupted. Numerous reasons -- often good ones -- exist: the student changes the company, the company moves resources (student included) to other activities, the interest of the company to the project ends, solution to the problem is found from other sources, etc. In all cases the situation is the same -- continuation of the work is broken, and the thesis-related work is in danger of not being exploited and the thesis is not completed.

D. 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.

The *communication-related issues* are:

Wall between supervisors: As companies and academia do not always 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.

IPR boundaries: In companies where products and IPR (Intellectual Property Rights) play a major role, it is common 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. 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 have been used by the students to artificially pump the importance of the research in company terms.

E. 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* [2; 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. 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*. This is the way for *experience transfer* and *communication* between software professionals and theses related stakeholders in a well applicable form.

The aim is to form a set of concrete antipatterns to help all stakeholders. The work has begun and finalization of it is future work; especially the limited space in this paper does not allow presentation of the full documentation. 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. In the following the approach and an example of an anti-pattern are presented. As the findings are based on our long and reasonably wide experience in the role of supervisor in our universities, the ideas introduced are applicable and reusable (for all counterparts) elsewhere.

An (anti-)pattern consists of the following components:

Name of the 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.
Corrections: How to fix / avoid the situation (if possible), the corrective actions.
Notes: Other notes related to the situation.

An example of an antipattern is shown in Table I:

TABLE I. ANTI-PATTERN EXAMPLE: NOT A COMPANY'S PROJECT

Name of the 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 and explicit agreement between all stakeholders. Use internal development topics instead of company projects.
Notes: Internal development topics are possible if the company has common processes or technologies.

We have preliminary analysis of all the problems listed in sub-sections IV.B to IV.D and prepared a skeleton of the complete list of these in pattern format. Additional work of the authors in the same problem area related to the industry PhD theses is available in [8].

V. DISCUSSION AND CONCLUSIONS

We expected that analysis of the sheer number of theses we aimed at covering would prove to be an impossible job, simply because there are so many problems that the students might encounter. Indeed, 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 problems fall in a reasonable number of categories. Obviously, common problems that one can encounter while composing a thesis in academic context are relevant to industry theses as well. Here we have overlooked such and focused on those that by necessity are related to the industry context.

One interesting note in the analysis of the problems 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 *instructor is a former student*, 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 are not 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 everywhere, and hence the learnings will bear significance outside the national setup. Because of the bi-national set of authors we have opportunity to study this aspect in the future work. Moreover, we are open to further collaboration with other countries.

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 present the situation and authors' experience in mind, while the journey to this point has had a major effect on the considerations that have motivated the work and are documented in the patterns. 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.

In this paper we did not have opportunity to transfer the whole list of problems to the anti-pattern format and handle these in detail. Here, in relation to the research questions, the problems are listed and categorized (RQ1) and the anti-pattern structure is introduced to point out the symptoms (RQ2) and to introduce the corrective actions (RQ3). Our plan is to extend this paper to document the results using the proposed anti-pattern structure.

To succeed in composing industry theses requires certain *maturity* and broad mind from all the involved parties. Clearly, there are differences in the view that the universities have on industry theses. Depending on how familiar companies are in working with universities, theses on company topics can be regarded as a nuisance for a company, or something that is a vehicle to advance the company's direct interests. Therefore, we believe that more thorough investigation of the collaboration abilities require a *model that considers the maturity of collaboration* from both company and university perspective. 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 our prime direction for future research. Instructions.

Finally, conducting 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 typical problems and structured these in a form of eleven anti-patterns. For each anti-pattern we propose ways to prevent and mitigate the problem.

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