Improved Support for Master's Thesis Projects in Software Engineering

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Abstract

The aim of the project described in this report was to develop improved support for both students and advisors in the different phases of Master's thesis projects in software engineering. The work was done in several steps, including a web-based survey among students; an interview study with students, supervisors and examiners; formulation of a support framework; and evaluation of the developed support. The main results of the project are improved understanding of the challenges of thesis projects, a support framework for different project phases, and examples of concrete support for different situations. We believe that the findings are relevant for Master's thesis projects in areas other than software engineering.

Key words

Master's thesis, software engineering

Sammanfattning

Syftet med det projekt som beskrivs i denna rapport var att utveckla stöd för både studenter och handledare i olika faser av examensarbeten i programvaruteknik på avancerad nivå. Arbetet har utförts i flera steg, härunder en webbaserad kartläggning bland studenter; en intervjustudie med studenter, handledare och examinatorer; formulerande av stödmaterial och utvärdering av det utvecklade stödet. Projektets huvudresultat är en förbättrad förståelse för examensarbetens utmaningar, ett stödramverk for olika projektfaser och konkreta exempel på stöd för olika situationer. Vi tror att resultaten är relevanta för examensarbeten inom andra områden än programvaruteknik.

Nyckelord

Examensarbete, programvaruteknik

Contents

Introduction

Master's degrees are awarded by academia, while Master's thesis projects are often done in collaboration with industry or a research group. The aim of the PIFF[1] project was to improve knowledge exchange between academia, industry and research during Master's thesis projects, supporting both students and advisors in the different phases (planning, execution, and grading/assessment) of Master's thesis projects in software engineering. The project was done in collaboration between Mälardalen University, Blekinge Institute of Technology and Lund University. It was funded, in part, by a grant from the Swedish Agency for Networks and Cooperation in Higher Education.

Knowledge in software engineering is becoming increasingly important for Swedish industry as the amount of software in products and systems increases. Several Swedish universities have established educational programs in the area, while conducting internationally successful research in software engineering. Research methods are characterized by being cross-disciplinary, as traditional methods of research in natural sciences and engineering is often combined with methods from areas such as social sciences to study complex processes involving both technical systems and human subjects.

All education in software engineering should provide the students with the tools necessary to work with development and maintenance of software in a disciplined manner. In addition, education at the Master's level should give them insight into research in the area and prepare them for possible research studies. Software engineering research can generally be described as the scientific study of technology, methods, and processes for development and maintenance of software.

During a thesis project, students are expected to use the knowledge and skills acquired in earlier courses to complete a work more comprehensive than in their earlier education and in a more independent manner. For students in software engineering, this usually means solving a task related to development or research or a combination of both. According to the Swedish Higher Education Act, university degree programs shall provide students with skills in formulating and solving problems as well as in seeking and evaluating knowledge at a scholarly level.

The best known set of guidelines for software engineering education (IEEE/ACM, 2004) states that students should conduct a comprehensive project in order to apply and deepen their knowledge. These guidelines are aimed at education at the Bachelor's level and focus on professional skills in addition to topics in software engineering and supporting subjects, such as computer science and mathematics. Thus, the connection to research and skills in research methods required for Master's level education are not covered by these guidelines.

Formal requirements on thesis projects have traditionally not been adapted to specific subjects such as software engineering and, consequently, tend to be quite general. Some institutions and research groups, however, have formulated guidelines for thesis projects, which are presented in the form of reports, books, and web pages. While such guidelines may be useful for different stakeholders in a thesis project, including academic and company supervisors, most are primarily targeted at students. One Swedish example is the book by Höst et al. (2006), which served as a starting point for the PIFF project.

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[1] PIFF is an acronym for the Swedish project title: Programvaruexjobb för Industri och ForskningsFramgång

The overall purpose of the project was to enhance students' learning outcome of conducting Master's thesis projects in software engineering. The concrete goal was to produce resources to support the different phases of a thesis project, such as formulation, conducting, supervision, and grading. An important sub-goal was that these resources should be suitable for thesis projects conducted in an academic research context as well as in an industrial context. Thus, the focus is on providing guidelines for developing the students' knowledge and skills in two complementary areas:

- Industry-relevant methods for development of software

- Scientific research methods in software engineering

The stated goal that scientific research methods should be included in all thesis projects is motivated, in part, by the requirements of the Bologna process and, in part, by the need for recruiting researchers. The focus on industry-relevant methods aims to increase the students' employability, thus making study programs attractive for students while meeting the needs of industry. It is expected that the results of the project can be generalized to other subjects than software engineering, in particular in other areas where cross-disciplinary methods are important.

Method

The objective of the project has been to provide support for all involved roles in Master's thesis projects. The development of this kind of support has gone through a number of steps, the first steps with a descriptive focus in order to understand the needs, and the later steps with a more normative focus in order to develop and evaluate concrete support material. The method for the whole project is outlined in Figure 1. Even if the steps were, to some extent, carried out overlapping, the main parts of them were carried out in sequence as presented in the figure.

In the first step a web-based survey was used to understand how students see the requirements on general skills, such as presentation and writing, in a thesis project. In step 2 an interview study was carried out with different roles in thesis projects. The focus of step 1 and 2 was to obtain understanding from ongoing and recently finished projects. Step 2 was concluded by formulating a framework for support for different roles. In step 3 a set of guidelines were formulated. These guidelines were evaluated in step 4, through a review conducted by students. The method applied in each step is further described in the next section.
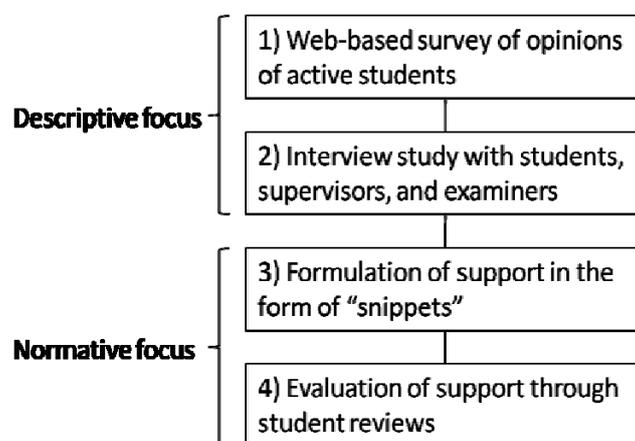

Figure 1: Overview of the method used in the project

Results

This section describes each of the four steps outlined in the previous section and the results from these. The project has also resulted in a number of published papers, which are marked with asterisks in the list of references at the end of this report.

Step 1: Web-based survey

Development of generic skills can be as important as domain-specific knowledge within a higher education. We created a questionnaire on the generic skills involved in a Master's thesis project and how well the development of such skill was supported at each university. Seventeen different skills were included, selected from a general list of generic skills created within the Bologna process. The questionnaire was implemented in a web-based tool and requests sent out to students who were at or close to finishing their theses. A total of 23 answers were obtained.

The generic skills "Capacity for analysis and synthesis", "Will to succeed" and "Problem solving skills" were considered the most important in order to finish the thesis, while "Capacity to adapt to new situations", "Initiative and entrepreneurial spirit" and "Interpersonal skills" were considered the least important. "(Academic) writing skills" and "Research skills" were the ones that were considered to be trained the most during the thesis project. A majority of students thought that generic skills were very important for their future career (average of 3.43 on a scale from 1-4 with 4 being "Very high degree") while the support by the university in developing generic skills were considered somewhere in between (average of 2.87 on the same scale, i.e. between High and Low degrees).

On an open-ended question on what the universities could do to better support the development of generic skills, students remarked that they should focus more on skills needed in industry, have more and earlier courses similar to the thesis work, and introduce academic writing courses early in each program.

The survey is described in more detail by Feldt et al. (2009).

Step 2: Interview study

As a second part of the descriptive work in the project it was observed that there was a lack of knowledge of what was seen as the most difficult parts in conducting a Master's thesis work. This did not only concern students, but also other roles that are involved in a thesis project. First of all, it is of course necessary to investigate what support is needed for students. After that it is also necessary to investigate what support is needed for the supervisor. Since many Swedish thesis projects are conducted in industry, it is necessary to consider both an internal supervisor at a university and an external supervisor in industry. In addition to these roles there is also an examiner who is responsible for approving the work, and assuring that the right level of quality is achieved. In this study the following roles were investigated: student, external supervisor, and examiner.

The investigation was conducted through a set of interviews with four students, one examiner and three external supervisors. Each interviewee were interviewed for about an hour, and based on this the following topics were investigated:

- Characterization of Included Theses, Students, and Organizations Involved, which gave sufficient background material to get an understanding of the involved thesis projects.

- Characterization of the Master's Thesis Project Process, which showed that a typical thesis project was divided into a number of steps.

- Requirements on Thesis Projects According to the Interviews, which identified which requirements the interviewees believed to exist on thesis projects.

- Objectives and Incentives for Different Stakeholders.

- Results of Thesis Projects, which focused on how different types of results were treated by companies.

- Conflicts and Discussions, which showed examples of typical discussions in thesis projects. Even if there were no major conflicts, it is natural that different stakeholders have different priorities.

- Identified Improvements for the Thesis Process, where the focus was on identifying improvements to the typical thesis project process.

Based on the collected data and the analysis it was possible to construct a framework which classifies the needed support in the following levels:

1. A general level with support for all types of thesis projects

2. A mid level of support where different kind of support is given to academic projects and industrial projects

3. A detailed level of support where industrial projects get support for six different kinds of projects and academic projects for typical research approaches, such as case study, experiment, survey, etc.

This is further described by Höst et al. (2010).

Step 3: Formulation of support

To address the varying levels of quality and grading that is common within Master's thesis courses Blekinge Institute of Technology have, partly as part of the PIFF project, worked on a thesis quality framework (Feldt, 2008). The framework is based on four rubrics that cover the four main parts of a thesis project: proposal rubric, thesis rubric, project rubric and presentation rubric. A rubric is a matrix showing the major quality criteria for a task or result/artifact. For each criterion it also states a number of quality levels that can be achieved. This helps clarify what is better and worse quality both for the student but also for supervisors and other involved faculty members. It can be used in a summative way or normatively to guide while performing a task.

In addition to rubrics, the quality framework clarifies the process and requirements on all roles involved. It also adds a faculty reviewer that takes part early and late in the project, by using the proposal rubric 2-3 weeks into the project to comment on the quality of the proposal, and by using the thesis rubric when the thesis is finished to help judge and grade the end result. The rubrics have been developed in an iterative process where feedback from students and teachers has been used to refine and shape them. All but the thesis rubric has four quality levels for each criterion, and between five and 15 criteria per rubric. Since the thesis rubric is the basis for the final course grade it needs to be more fine-grained and has

eight levels for 10 different criteria. This should probably be further decreased somewhat, since some teachers feel that it is currently too complex.

The continuous evaluations of the framework has shown that students really like it, with over 90% of probed students (class-wide questionnaires have been used at several occasions) thinking that the rubrics are very highly or highly useful. Supervisors and faculty reviewers generally think the rubrics are too detailed and can require somewhat more work when used for grading. However, the effects on quality have been very promising with a steep increase in the number of theses that are published as research articles, or being part in research collaborations with industry. The use of faculty reviewers has also lead to a greater consensus among the faculty of what constitutes a good thesis. The whole process also ensures that variation in grading gradually decreases over time since supervisors and reviewers discuss the final grade and any differences of opinions.

Based on the thesis quality framework, we have started to develop a web-based tool called SE Theses Support (http://se-ts.weebly.com/), which is a concretization of the support framework first outlined by Höst et al. (2010). The tool is mainly built using "snippets", which are relatively short texts providing advice on specific aspects of a thesis project. These are structured in a modular fashion to allow new snippets to be easily added.

Some snippets deal with professional ethics and include resources such as an informed consent template and evaluation criteria for the quality judgment of theses and thesis projects, in order to regularly support software engineering students in thinking through ethical issues in their thesis projects. The aim is to increase the ability of future professionals to recognize and address ethical problems, to accept different ethical perspectives and allow for ethical pluralism (Dodig-Crnkovic & Feldt, 2009).

There are several snippets related to empirical research methods. Two methods, constructive research and case-study research, received particular attention in the course of the project. A constructive research method implies building of an artifact (practical, theoretical or both) that solves a domain problem (including a model for existing phenomena) in order to create knowledge about how the problem can be solved (or understood, explained or modeled), and if previous solutions/models exist, how the solution/model is better than previous ones (Dodig-Crnkovic, 2009).

Constructive research gives results which can have both practical and theoretical relevance. The research should solve some related knowledge problems, such as

- Feasibility: How a previously unsolved problem can be solved.

- Novelty: How a previously solved problem can be solved in a new way.

- Improvement: How a previously solved problem can be solved in a better way than before. The emphasis should be on the theoretical relevance of the construct. What are the elements of the solution central to the benefits? How could they be presented in the most condensed form?

Related to this project, work has been conducted in order to provide guidelines for conducting case study research (Runeson & Höst, 2009). Guidelines are presented for the following phases of case study research: Case Study Design and Planning, Collecting Data, Data Analysis, and Reporting. The guidelines include a set of checklists that can be used by the

researcher during the phases of the research and by a reader when judging the quality of a published case study. The guidelines formed the basis for a more limited set of guidelines for Master thesis projects in the form of snippets.

Step 4: Evaluation of support

The evaluation of the developed support by student reviews was not completed within the timeframe of the project, but there has been an ongoing review of the produced material by discussions within the project group. Material to be used by evaluation groups of students has been produced (Höst et al., 2009) and we hope that it will be possible to enlist students for such groups in the near future. The remainder of this section briefly describes the planned work of the evaluation groups.

At each university, an evaluation group should be formed consisting of three students who are currently conducting their Master's thesis projects. These groups perform the evaluation in two phases. In the first phase, the students work individually and, as the first step, each student is asked to answer a few general questions about conducting a thesis project. The students then start to learn about the project by reading a brief project description and two of the papers produced in the course of the project (Feldt et al., 2009; Höst et al., 2010). After studying this material and the existing snippets, each student is asked to provide feedback on the framework and the snippets. This first phase of the evaluation is expected to require approximately eight hours work on part of the students.

In the second phase, the evaluation groups at each university meet to collectively produce a report. The report should address a set of closed and open questions about the survey, the framework, and the existing snippets. The closed questions are formulated as statements, which the students are asked to grade on a scale from 1 to 5, where 1 means "disagree completely" and 5 means "agree completely". The second phase of the evaluation should comprise four hours of work for the evaluation groups.

Although it is believed that this use of evaluation groups will provide valuable feedback about the support framework, it should furthermore be evaluated over time by having students and supervisors use it during thesis projects and collecting feedback from them.

Discussion

During the project we have found that there is a clear need to produce guidelines for persons involved in Master's thesis projects. Not only students are unsure about the exact requirements on a thesis project and how to best carry out this kind of project. To some extent this is due to the nature of large projects. There cannot be any guarantees that a certain way of working will produce the results that are expected and projects are so different that it is hard to formulate "objective requirements" on the results of a thesis project without taking the process carried out in the project into account. Criteria for assessment must be more elaborated.

The main result of this project consists of the following parts:

- Improved understanding of the perceived difficulties and requirements of thesis projects. This has made it possible to formulate requirements on guidelines for different parties.

- A framework for support. In the beginning of the project we expected to produce different guidelines for different roles, but the final result of the project is more aimed at different support for different kinds of thesis projects, and we have found it possible to give the same support to all involved roles. In fact, it is seen as an advantage that the same information is given to all roles. The framework spans over all needed support, even if all support was not developed within the timeframe of the project.

- Example of support for different situations in the form of "snippets". We have found it possible to formulate this support.

Even if there has been an ongoing evaluation of all produced material there is a need to further evaluate and improve the results. This is probably a task that must span over several years before a "final result" can be obtained.

It is interesting to put the proposed support in the context of the requirements on higher education. Higher education is required to give the student the ability to i) make independent and critical assessments, ii) independently identify, formulate and solve problems, and iii) have a readiness to face changes in their profession (The Swedish Higher Education Act, 1992:1434). The Master's thesis project is an important part in giving the students these abilities. It could be argued that too much support makes it "too easy" for the students and that they thereby do not obtain these abilities. We argue however in the opposite way: we believe that without sufficient support the problems in the thesis project may be "too hard" in the sense that it could cause students to follow the first solution path to the problem, without reflecting on alternative solutions, and without being aware of what different solutions there are. This means that the type of support that we have outlined is necessary for the students to accomplish the goals of higher education.

It is furthermore interesting to compare the project with a recently published set of guidelines specifically targeting graduate level curricula in software engineering (iSSEc, 2009). These guidelines, like the aforementioned undergraduate guidelines of IEEE/ACM (2004), recommend that students must apply and demonstrate their knowledge and skills towards the end of their study program in something similar to a thesis project. They stress that this should include software engineering skills as well as generic skills of the type discussed by Feldt et al. (2009). It is interesting to note that the guidelines include skills in ethical and professional conduct in the required learning outcome of Master's programs. This has also been one of the areas addressed by PIFF (Dodig-Crnkovic & Feldt, 2009). On the other hand, they include no requirements related to software engineering research or scientific research methods, noting that the guidelines target programs focusing on software professionals rather than future researchers. As we have already stated, we believe that education at the Master's level should include a research component.

In summary, the PIFF project has gone through four main steps. The first step was a web-based survey on the importance of generic competencies to students that were conducting or had recently finished their Master's thesis project. The second step was an interview study. Based on nine interviews of different roles in software engineering Master's thesis projects, it is concluded that different roles have different objectives with thesis projects. This means that the expectations for the projects can differ for different roles, and that the perceived challenges can differ as well. In the third step of the project, a model to support different roles and different types of thesis projects was formulated. This framework is based on four rubrics that cover the four main parts of a thesis project: proposal, thesis, project, and presentation. In addition, the framework clarifies the process and requirements on all roles involved. Finally,

the fourth step consists of evaluating the framework. This step, which has not been fully realized yet, involves forming evaluation groups of students at each of the participating universities. The framework will be evaluated further as it is used by students and advisors in future thesis projects.

The project has focused on thesis projects in the area of software engineering. This is an area that is characterized by its multi-disciplinary nature. Relevant problems include those from natural science related areas, such as computer science and mathematics, as well as problems from areas within social sciences and economics, such as organization theory and behavioral theory. We believe that the findings from the project are also relevant to thesis projects in other areas than software engineering.

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(* = direct result of this project)

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