A Structured Process for Supervising Students' Final Theses and Projects in Computer Science

https://doi.org/10.3991/ijac.v15i1.27211

Sigrid Schefer-Wenzl(✉), Igor Miladinovic
University of Applied Sciences Campus Vienna, Vienna, Austria
sigrid.schefer-wenzl@fh-campuswien.ac.at

Abstract—Theses for bachelor's and master's degrees are opportunities for students to dive deep into a research question and gain in-depth knowledge about a research topic. At the end of a curriculum, theses act as a kind of bridge between the educational stage and work or further study. Thesis supervision is a resource-intensive task and often a critical factor for the quality of a thesis. After decades of experience with different methods, we have developed a concept for continuous thesis supervision and applied it to two specific degree programs at our university, the Bachelor's program in Computer Science and Digital Communication and the Master's program in Software Design and Engineering. Compared to traditional supervision methods, this concept has led to a higher adherence to deadlines and to a higher quality of the final theses. In this paper, we present our findings on different types of supervisors and our concept for continuous thesis supervision, which can be adapted to each identified supervisor type. This concept comprises several methods, intended to inspire other supervisors to choose the set of methods that best suits their needs. We also describe how this concept can be adapted for project-based courses.

Keywords—supervision, higher education, bachelor thesis, master thesis

1 Introduction

At the end of a degree program, students are usually required to write a final scientific thesis to demonstrate their maturity and readiness to investigate a complex topic in depth. This requires two major changes in student behavior. First, they must move from guided learning in larger groups to self-organized learning with an individual topic. Second, the topic and research question of a bachelor's or master's thesis is usually new, and the outcome is unpredictable, which is different to other courses in a degree program. Thus, students work on a complex problem, while most other courses deal with complicated topics [1]. The main difference between complex and complicated problems is that solving complicated problems requires expert analysis from students, followed by the selection and application of one among several good practices. To solve complex problems, students need to reconsider existing solutions, explore and sense their implications, and find new solutions iteratively and evolutionarily.

It has been repeatedly shown that the supervision process is an important aspect for the success of a thesis project [8]. Different types of supervisors have been identified [12], and there are several recommendations and guidelines for supervising scientific theses [6]. In this paper, we analyze the goals and challenges of scientific theses, present a categorization of supervisors along two dimensions—"responsibility" and "autonomy"—and derive a recommendation for a supervising process addressing all types of supervisors. We have been using this process at our university for several semesters and have seen an increase in the number of students who complete their thesis on time and an increase in the quality of their work. This paper is an extension of our previous work presented in [13] and also includes the adaptation of our concept for project-based courses.

The remainder of this paper is structured as follows. Section 2 presents related work in the field of supervising bachelor's or master's theses. In Section 3, we analyze the main goal of theses, as well as corresponding critical success factors and necessary conditions. Main challenges for writing theses and their potential root causes are described in Section 4. Section 5 presents our concept for supervising scientific theses, including a classification of four different supervisor types. In Section 6, we demonstrate how this concept can be replicated to project-based courses, and Section 7 concludes this paper.

2 Related work

Several authors discuss that the supervision process is highly influenced by the personal relationship between supervisors and students. In [2], the different responsibilities of students and supervisors are analyzed, and their match in expectations according to who is responsible for which task in the supervision process is evaluated. Their study shows that there exists a significant mismatch between students' and supervisors' expectations regarding who is primarily responsible for which elements in this process (e.g., topic selection, initiation of meetings, checking on progress, methodology discussion or requesting feedback). An alignment between expectations is highly recommended to improve results. Similarly, Grant [3] discusses the complex relationship between students and supervisors and derives three different supervision styles: traditional-academic, techno-scientific and psychological. The traditional-academic style is formal and asymmetric, where students have a passive role in the supervision process. The techno-scientific style focusses on the development of students' research skills. This also is an asymmetric style resulting in a high degree of dependency of students on their supervisors. Psychological supervision styles are characterized by an equal power distribution between students and supervisors.

In [4], an alternative model to the traditional one-to-one supervision is presented. This model aims at utilizing the benefits of group supervision and peer feedback to overcome the negative effects of students being supervised by only one person. They emphasized the benefits of student colloquia where students discuss their ideas, their positive and negative experiences, as well as other thesis-related problems. In addition,

early individual and group feedback is recommended. Holmberg [5] also discusses three different supervisor roles. According to this research, supervisors either act as coaches, who see a thesis as a joint project, and the supervisor primarily acts as a trainer to support the student. Other supervisors take the role of a consultant, where supervisors act as a resource that students have the responsibility to use according to their individual needs. The third type of supervisor acts like a parent who carries the whole responsibility of the supervision process.

The authors of a study presented in [6] conclude that effective supervision of theses should focus on the following two parts: support at the beginning to clarify the aim of the thesis, as well as support of students in applying the methodology.

The main challenges in supervision processes are analyzed in [7]. They found that one of the main difficulties is to find the right balance between student autonomy and supervisor direction, as well as between authorship and responsibility. In addition, the diversity of students implies that there is no perfect supervision process that fits to the needs of all students. Supervisors also need to allocate time between students equally. Furthermore, giving feedback is a crucial point.

The importance of metacommunication in the supervision process is discussed in [8]. Metacommunication hereby refers to the communication between supervisors and students about certain aspects of the supervision process. Again, the authors emphasize the importance of early-phase metacommunication where students clarify the roles of supervisors and students, expectations, and how the process is structured. In addition, regular metacommunication contributes to a better communication between supervisors and students.

Several authors evaluate how blended learning approaches can facilitate and improve the supervising process. The integration of agile methods from software development, such as using a Trello board, is proposed in [9]. In [10], several parts of the supervision process are supported by an online tool. Especially tasks concerned with thesis administration, exchange of information and collaboration have a high potential for blended learning tool support.

3 Goal of bachelor's and master's theses

Successful completion of a thesis demonstrates several skills. First, students show a deep understanding of a specific topic, which in our degree programs is in the field of computer science. Second, they demonstrate the ability to work in a self-organized manner because there is no strict process to follow in order to be successful, as is the case in most other courses in a degree program. Finally, interpersonal skills are required to work with supervisors and stakeholders in the company (in the case of final theses that are done in collaboration with our industrial partners). All these skills are also in high demand by industry, so we can define the ultimate goal of a thesis as preparing students for their careers in industry. This is shown in the goal tree in Figure 1.

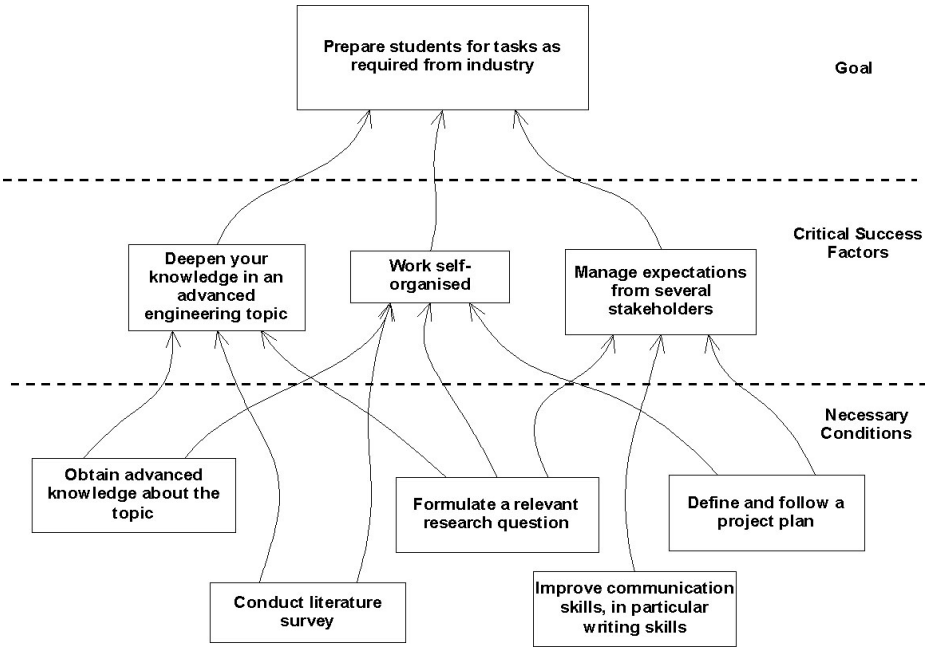

Fig. 1. Goal tree of a bachelor's or master's thesis

In order to develop these skills required to achieve the goal (also called critical success factors), several necessary conditions must be met. For example, students must build advanced knowledge of a particular topic based on what they have already learned in their studies. They must conduct a comprehensive literature review and formulate a scientific research question. These three conditions are necessary for students to deepen their knowledge of an advanced computer science topic (see Figure 1). In order to work in a self-organized manner, they must also define and follow a project plan that also serves as a commitment to completing each task. Finally, students must also have solid communication skills to meet stakeholder expectations.

4 Challenges of a thesis

As we have seen, a bachelor's or master's thesis is expected to be the final preparation for the students' further career. However, at our university, we experience a number of students each year who do not successfully complete the thesis, even though they have successfully completed all other parts of their studies. In this section, we will discuss the reasons for this based on the feedback we have received from students.

At our university, there are firm deadlines for submitting the theses. If students miss this deadline, they will not be able to complete their degree. Therefore, the most undesirable effect (UDE) related to the supervision of bachelor's and master's theses is that students cannot meet their deadline. In Figure 2, we analyze the main reasons leading to this effect in a current reality tree focusing on this UDE. We identified the

following three causes of this UDE: inadequate writing skills, inadequate self-study skills and lack of time. As shown in Figure 2, there are other causes of these three deficits, all of which lead to two main causes: a strong focus on technical skills in a computer science curriculum and inadequate thesis supervision.

Once we identified the root causes, we considered how to address them. First, we re-designed our curriculum to include more professional skills courses. For example, we introduced a course on "Scientific and Technical Writing" in the third semester of our bachelor's program and some courses in almost every semester that require students to write a term paper. To make the practical relevance of the courses clearer, we have combined them with the engineering courses into modules, with a common module grade for both courses. This alleviates the first root cause. More about the structure of our bachelor's program can be found in [11]. Second, we have developed and implemented a concept for the supervision of bachelor's and master's theses that supports the elimination of the second cause: inadequate supervision. In this paper, we present this concept and discuss its benefits and challenges.

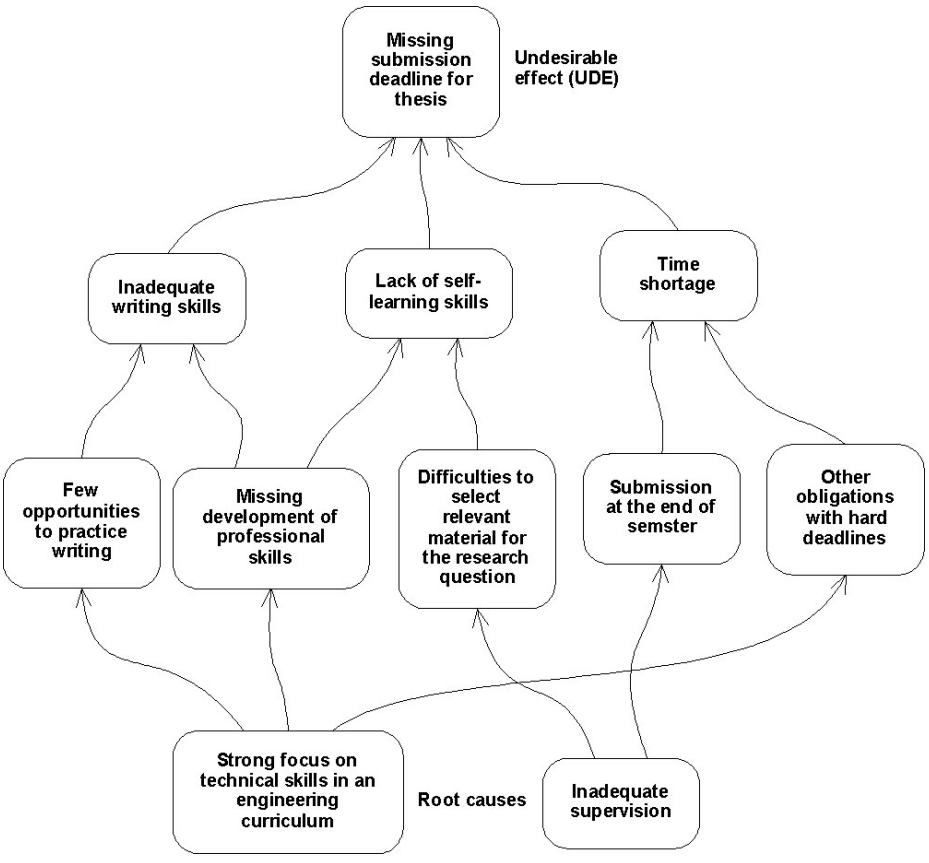

Fig. 2. Focused current reality tree for an unsuccessful bachelor's or master's thesis

5 Concept for a supervision process

As mentioned in Section 2, there are different types of supervisors. We found the greatest differences in the perception of responsibility for the thesis and in the perception of students' abilities to work in a self-organized manner. On this basis, supervisors can be divided into four categories, as shown in Figure 3:

1. **Controller:** The supervisor takes the main responsibility for the thesis and for the whole process. The supervisor specifies the topics, sets deadlines and usually has a clear expectation of the outcome of the work.
2. **Gatekeeper:** The supervisor works with students, who take responsibility for the thesis writing process and organize themselves. The supervisor has a clear expectation of the outcome and feels responsible for the outcome.
3. **Supporter:** The supervisor defines the topic of the thesis and a clear process for supervision. During the process, students have defined submissions to track the progress of the work and receive feedback. Students have the primary responsibility for the outcomes of the thesis.
4. **Coach:** The supervisor allows students to work in a self-organized manner. Coaching sessions are provided at the students' request. Students have the primary responsibility for the outcomes.

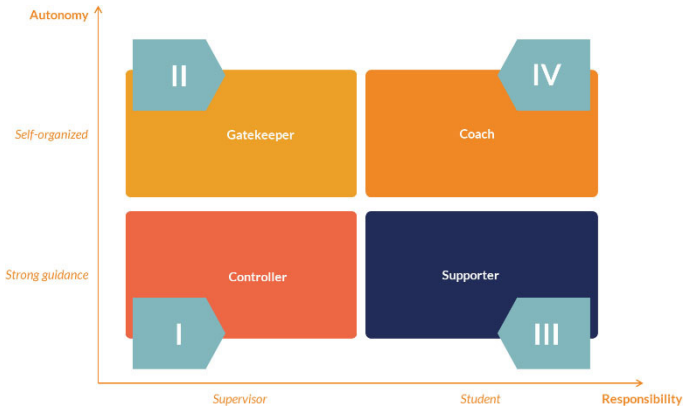

Fig. 3. The four supervisor types

We designed and implemented a supervision process that can be adapted to any type of supervisor. The process defines clear and continuous guidance to support students according to their needs. The supervisor ideally applies the process individually for each student to support different student types.

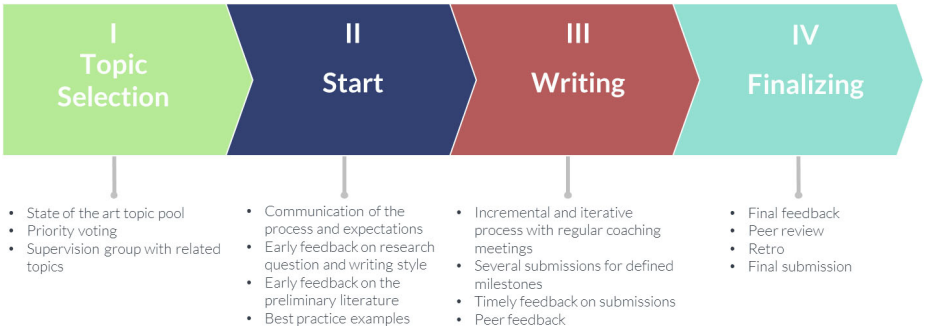

Fig. 4. The four phases of continuous thesis supervision

Figure 4 summarizes our thesis supervision process, which takes into account the goals and challenges of theses described in Sections 3 and 4. We have divided this process into four sequential phases. The first phase is about selecting the topic. For this purpose, we organize a kick-off meeting where we introduce the potential topic pools of the respective supervisors. During this event, students can clarify questions and also propose their own ideas and discuss them directly with the supervisors. Students can then vote for three different topics and are assigned to the topic that best suits them. Each faculty member supervises a group of students who are all working on related topics. This also allows students to inspire each other while being supervised.

The second phase begins with a meeting with the respective supervisor, in which we introduce the supervision process and communicate to the supervised group our expectations for a successful thesis project. We ask students to submit their research question, a first draft of the content, a first subchapter, and a preliminary bibliography within about two weeks. We provide feedback on these parts in a timely manner so that any errors and misunderstandings can be corrected immediately. To inspire and support students at this stage, we also share best practices from previous years.

Most of the writing occurs in the third phase. At the beginning of this phase, students have a good, but almost blank, outline for the thesis, and at the end, they have a draft version of the complete thesis. During this phase, we hold regular coaching sessions (usually bi-weekly) where we discuss the status of the thesis, next steps, and current and upcoming challenges with each student coaching group. In addition, we set optional deadlines for the submission of parts of the thesis (e.g., the next 10 pages or the next chapter). Students are free to choose whether they submit their progress by the given deadlines and whether to attend the meetings. For submissions, which are usually monthly, students receive timely feedback that they can incorporate into the next submission. All submissions are set and done in our Moodle course. Students also receive peer feedback from other students in the coaching sessions, where we discuss feedback on their work. Therefore, it is important that all students work on related topics in a coaching group.

In the fourth phase, students submit their preliminary final theses in our Moodle course. The deadline is usually 2–3 weeks before the official submission date. This gives us the opportunity to provide final feedback on the complete thesis and also to organize a peer review, where each student not only reviews and gives feedback on

the theses of two other students, but also receives feedback from two other students. At this stage, there is also a final coaching meeting where we discuss the feedback on the preliminary final draft and conclude the supervision with a retrospective reflecting on what worked well, what could be improved and why. After this, students are ready to formally submit their final theses.

By providing early feedback in the first phase, we can in particular mitigate difficulties in selecting relevant material for the research questions. By introducing regular deadlines and gradual submission of theses, we ensure that students work on their theses continuously and do not put them off until final submission at the end of the semester. This concept, thus, eliminates "inadequate supervision" as the cause of the current reality tree (Figure 2).

6 Applying the supervision process in other courses

The presented supervision process is not limited to bachelor's and master's theses. It can be applied in other courses, where students work on larger projects. Therefore, we evaluated its application on other project-based courses in our degree programs. In this section, we describe the application of the supervision process from Section 5 for project supervisions at bachelor- and one master-level courses.

Similar to Section 5, for project-based courses, we can differentiate between the four basic supervisor types: controller, gatekeeper, supporter and coach. Independently of the origin of a project, which can be a research or industry project, the supervisor can feel more or less responsible for the outcome, so that we have the same categorization for the X-axis (see Figure 3). The team of students working on a project can be more or less self-organized, as reflected by the Y-axis. Therefore, the process presented in Section 5 supporting any kind of thesis supervision should be at least partly reusable for project-based courses.

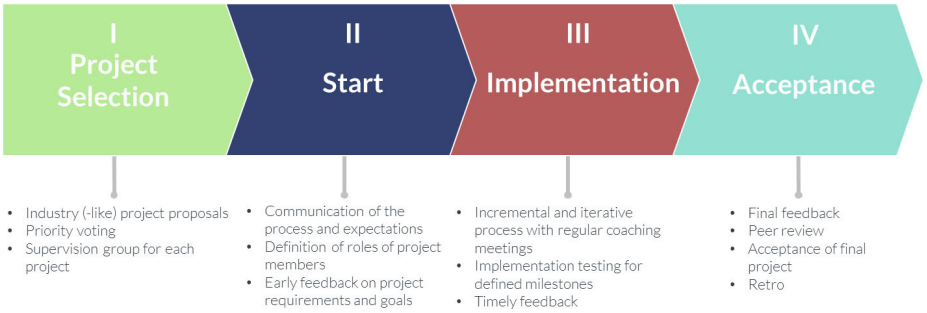

Fig. 5. The four phases of continuous supervision in project-based courses

However, the thesis supervision process from Figure 4 must be adapted for project-based courses, as illustrated in Figure 5. Again, the process comprises four sequential phases. The first phase is project selection. In a kick-off meeting, we introduce together

with our industry partners the potential projects and their supervisors. Afterwards, students vote for three different projects and are assigned to one of them. Usually, a team of 3–5 students is working on a project together with the same supervisor.

Starting with the second phase, the process is project specific. Each supervisor communicates the supervision process to the supervised project team. Students need to submit a document specifying requirements and goals of the project. This document is also the basis for the grading at the end of the project. The supervisor provides feedback on this document in a timely manner to clarify the project scope early.

In the third phase, the project is iteratively and incrementally implemented. During this phase, supervisors hold regular coaching sessions to discuss the status of the project and next steps, and to help with any implementation problem. The implemented features are tested in these sessions, and the supervisor provides feedback on the current project status.

In the fourth phase, students submit their final project for the acceptance testing. The project is reviewed by other project teams, as well as by the project industry partner. The implemented features are compared with the requirements document. Finally, students get final feedback from the supervisor and discuss important leanings in a retrospective.

7 Conclusion

We developed and implemented the presented concept for continuous theses supervision for the first time in the summer semester of 2017. We started with four groups of students and were the only two lecturers with this concept. In total, 40 out of 50 students were able to complete their thesis on time (80%). In our groups, we supervised 22 students according to the given concept, of which 19 finished on time (86.4%). In the other groups, there were a total of 28 students, of whom 21 finished on time (75%). After this year, we started to transfer our concept to other groups and share it with other supervisors. Today, more than 75% of our students are supervised following this concept.

Our preliminary findings are that there are a few key success factors for a supervision of a bachelor's or master's thesis. First, the process and expectations need to be clearly communicated at the beginning. Second, support and feedback at the early stage of a thesis helps students to find an appropriate topic and formulate a research question, which is a precondition for a successful thesis. Third, continuous work on the thesis and intermediate feedback from the supervisor increases on-time delivery rate of theses.

We already replicated this process with the described adaptations on project-based courses. Also here, we have experienced a higher success rate of the projects in comparison to an unstructured supervision.

In our future work, we plan to identify an optimal supervision process for different supervision styles, to further evaluate this concept as well as to investigate reasons for a failure to complete theses. According to these reasons, we will introduce further changes in the curriculum, or adaptions in the proposed supervision process.

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9 Authors

Sigrid Schefer-Wenzl is a senior researcher and lecturer at the University of Applied Sciences "FH Campus Wien", Vienna, Austria (e-mail: sigrid.schefer-wenzl@fh-campuswien.ac.at).

Igor Miladinovic is head of the degree program "Computer Science and Digital Communications" and "Software Design and Engineering" at the University of Applied Sciences "FH Campus Wien", Vienna, Austria (e-mail: igor.miladinovic@fh-campuswien.ac.at).

This is a revised and extended version of a presentation given at The Learning Ideas Conference 2021, held online June 14-18, 2021. Article submitted 2021-9-30. Final acceptance 2022-1-10. Final version published as submitted by the authors.