An Approach to Designing Software Engineering Thesis Papers

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Abstract: Thesis development proves most complicated for students, as it implies more than one final work product and involves facing deadlines. One of the most challenging aspects here is writing the thesis paper. Software engineering is marked by specific difficulties, since students focus on the software development and neglect other aspects, first of all, the thesis paper writing. Hence thesis paper writing demands significant support from the university. This paper presents a method of managing the thesis paper writing process for software engineering undergraduates. Mind mapping is used for the early design, fast feedback, and a wide discussion of the thesis paper plans. The method is implemented as a one semester course for last year undergraduates. The evaluation conducted indicates a significant increase in the quality of thesis papers.

1 INTRODUCTION

Preparing a thesis is no less challenging a task for students, than for organizations who instruct and tutor thesis writing at higher education institutions (Rapp, Kruse, 2016). Following (Davis, Parker, 1979), the thesis writing process takes one third of the total time allocated to obtaining the degree; and although these authors were discussing the doctoral thesis, the statement is also relevant for other types of theses. Most students, however, tend to underestimate the effort that a thesis demands (LaCourse, Rock, 2002). Hence, they need a considerable educational, resource and management support to write their theses properly (Aghaeea, Keller, 2016). Providing such support for undergraduates is especially challenging for a number of reasons. Firstly, undergraduates have fewer professional and academic skills than other kind of students, and most of them are working on the first thesis in their life. Secondly, they by far outnumber graduate and postgraduate students, so it is quite difficult to provide high quality one-to-one individual support. Software engineering involves an additional difficulty, while students have a lot of software development to do, and neglect preparing other work products, mainly thesis papers.

At our department, every year 30 to 40 undergraduates face the task of preparing a thesis. Besides individual supervision, we provide an additional kind of centralized support. Managing writing thesis proves to be one of the most significant parts of student work that needs to be supported.

There is a number of approaches to providing good quality thesis papers (Rapp, Kruse, 2016), (LaCourse, Rock, 2002), (Aghaeea, Keller, 2016), etc. However, there is a lack of approaches which would work in conjunction with the actual thesis development. Also, some additional techniques need to be used in the thesis development process to ensure collaboration and to encourage students.

Mind mapping (Buzan, 1995) is a widely known technique to structure and manage any kind of information. It is actively used in education, solving a wide range of tasks: supporting collaboration, stimulating critical thinking, improving memory power, etc. (Fun, Maskat, 2010), (Noonan, 2013), (Papushina, et al., 2017). However, this technique has not been used so far for the management of thesis writing at the department level.

The present paper describes a method for the management of thesis writing for software engineering undergraduates. The aim of the method is to support thesis design, to provide collaboration between the author, the supervisor and other department staff, to ensure fast feedback at an early stage of writing. The method is based on the mind mapping technique and the Comapping toolset (Comapping, 2017). It is implemented as a course for last year undergraduates. During the course, students develop plans of their thesis papers through following suggested patterns and guidelines. Students discuss

these plans with their supervisors and the course lecturer, and substantially modify them. Finally, every student prepares two or three drafts of his/her thesis paper, following the plan developed before. By teaching this course, the department closely monitors students' progress at an early stage of thesis writing. Further work is managed by student supervisors alone. The department staff then check the final versions of the theses. Our paper describes the method and course structure, and also presents some evaluation data.

2 RELATED WORK

There are a large number of books and papers on academic writing, e.g. (Annesley, 2010), (Swales, Feak, 2004), (Canagarajah, 2013). In (Stojmenovic, 2010) specific guidelines for writing papers on software engineering and computer science are presented.

There exists significant literature on development software documentation: see (Barker, 2002) for survey tools and methods. There is also a variety of approaches to writing user documentation (Weiss, 1991) and a vast literature on technical writing (Williams, 2000), (Wright, 2010).

However, academic and technical writing courses can help students in preparing their thesis papers only when their general writing skills are already high enough, which, in fact, does not prove to be the case even after taking these courses (LaCourse, Rock, 2002). Hence a special form of thesis development support is required.

There are a number approaches, techniques, and tools to support thesis development.

The problem of interaction between students and supervisors during thesis writing is considered in (Hansen, Hansson, 2015). The authors analyze web-discussions between students and supervisors, and reveal that one of the main topics of collaboration was «How to write».

Peer reviews to improve the quality of thesis papers are considered in (Aghaeea, Keller, 2016), (Aghaee, Hansson, 2013). The findings show a considerable investment of the approach to increasing thesis paper quality. Also, some limitations of the approach are reported: the motivation of students to write reviews, student review skills, the quality of papers to be reviewed. To apply the approach efficiently, thesis papers should appear as readable and well-understandable drafts quite early. However, our experience shows that working on the thesis paper is often the last thing that undergraduates do in their thesis projects, which leaves very little time to review and discuss the texts.

The necessity of a special course that is directly connected with the actual thesis project is argued in (LaCourse, Rock, 2002). An early 1-credit course for graduate students is offered. The course includes the following topics: time management, scientific method, thesis statement, justification and background, the structure of the thesis paper, and some other issues. The course aims to support the student's transition to an independent researcher. However, the course addresses to graduate students, who need to master individual research skills. Meanwhile software engineering undergraduates are less mature and academically oriented and focus more on acquiring basic professional skills.

A number of special software systems are developed to support thesis development: Thesis Writer (Rapp, Kruse, 2016), SciPro system (Aghaeea, Keller, 2016). These systems provide thesis guidelines, support collaboration between students and supervisors, provide facilities for peer-reviews, and allow to collect various statistics to improve the process. Such kind of software is useful for managing thesis development, yet it cannot fully replace special courses. Moreover, additional techniques need to be employed to encourage students to put more effort into writing and to facilitate thesis development process.

A promising technique for structuring and analyzing information that is actively applied in education is mind mapping (Buzan, 1995).

Teacher-centered and student-centered mind mapping modes are explored in (Fun, Maskat, 2010). The authors found that the active involvement of students in mind mapping is far more efficient than presenting them with high quality maps constructed by teachers.

Educational modules within the technical secondary school essentially using mind mapping are presented in (Tee, Yunos, 2012). Students use mind mapping for reading literature, revising, note-taking, etc. The study found the technique improves students' learning achievements.

There exists numerous evidence on using mind mapping in health education. In (Edwards, Cooper, 2010) mind mapping is considered as a teaching resource in clinical education. It is explained how to use this technique for preparing and reviewing lectures, and for examinations. To address the issues of poor paper quality, a faculty program is offered in (Bickes, Schim, 2010). The program includes a writing workshop, a revision of the grading rubric, and a system of blind review for grading student

papers. However, the program is provided mostly prior to rather than in conjunction with the actual thesis development. An interesting survey of mind mapping in health education is presented in (Noonan, 2013). 11 papers were analyzed, and some of them reported unsuccessful results of mind mapping. It seems that one of the crucial points for successful mind mapping is the students' openness and willingness to try new techniques. Otherwise, it is quite difficult to shift the situation.

(Somers, et al., 2014) and (Papushina, et al., 2017) report about applying mind mapping in business education. The former paper presents the results of an experiment, where undergraduate and MBA students, and faculty staff developed mind map models for the same complex topics. This revealed some interesting facts concerning students' abilities to integrate and apply knowledge. For example, the students represented their knowledge as a set of poorly connected «islands»; in contrast, the faculty staff developed densely connected models for the same topics. The latter paper discusses mind mapping software tools for education needs, and also presents the results of using mind mapping as a part of a Master's program in marketing. The students use mind mapping in outclass reading and to present the results of their research tasks, their mind maps being then discussed and evaluated in class.

Computer-supported collaborative mind mapping in software engineering education is considered in (Koznov, Pliskin, 2008), (Koznov, 2012). Mind mapping is used as an exam technique for the final software engineering course and for designing term papers and theses.

(Kokotovich, 2008) considers non-hierarchical mind mapping in industrial design. The author offers this technique for students and novice designers in the early phases of the problem-solving process. Non-hierarchical mind map means a network data structure.

Summarizing, there is no research on applying mind mapping for thesis development in the context of a special course. This idea is discussed briefly in (Koznov, 2012), but no integrated method has been offered so far.

3 MIND MAPS AND COMAPPING

Mind mapping was suggested by Tony Buzan in the 1970s to work more efficiently with any kind of information (Buzan, 1995). The idea is to use a simple diagramming notation: the primary (central) object is put in the middle, secondary objects, which clarify the meaning of the central one, are drawn around it and connected with it, etc. (Fig. 1).

Figure 1: An example of a mind map.

This approach is suitable for analyzing and understanding any kind of information, especially in case of large volumes. The approach is widely used in education, business, psychology, and other domains. There are also a number of software tools implementing the approach. Further details can be found in (Koznov, Pliskin, 2008), (Koznov, 2012), (Papushina, et al., 2017).

Comapping (Comapping, 2017) is a collaborative online mind mapping tool. It supports features such as easy drag and drop, smooth animation, large maps with smart auto-focusing features, etc. A tree-like notation (left-to-right mind mapping) is better for the computer-based support when combined with a layout algorithm, as it is easier to read and understand than the centre-based one. An example of a mind map in Comapping is shown in Fig. 2.

The tool allows sharing maps among any number of users, as well as notifying them about map changes. These changes are highlighted on the map with detailed information, and other users can review the changes and leave comments, making Comapping a suitable tool for professors to monitor student work.

4 METHOD

The main idea of the method is to use mind mapping for the early design of student thesis papers. It enables collaboration between department staff, thesis supervisors and students to develop a mature thesis plans following the patterns and guidelines recommended by the department. Our experience shows that students find it extremely difficult to make serious corrections to the paper when the bulk of it is already written. On the other hand, reading and correcting a poorly written text is far too laborious for

the supervisor and the department staff. The goal can be achieved more efficiently at the paper design phase. Just as visual models in software engineering (UML, SysML, etc.), and in business modeling (BPMN, EPC, SADT, etc.), mind mapping is able to provide easy information exchange and fast feedback.
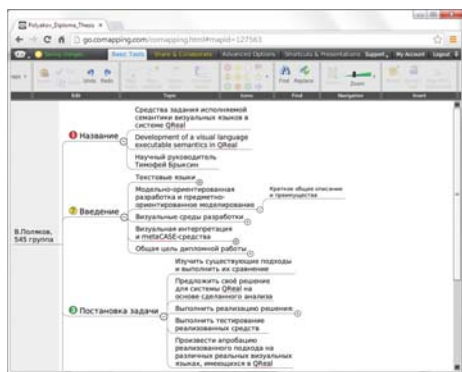

Figure 2: Example of a mind map diagram in Comapping.

The first steps of the method are defining thesis goals, specifying the results, and creating paper backbone (see fig. 3). The result of these steps is the mind map of a student's thesis paper. Then the introduction is planned and written, and the first two or three drafts of the paper are developed. Let us consider every step in more detail.
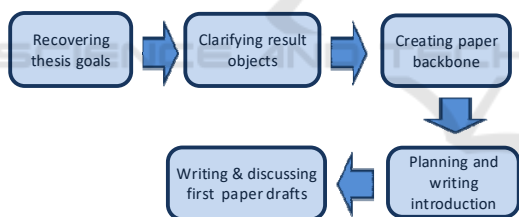

Figure 3: Method schema.

Defining thesis goals aims to reconsider and renew the goals of the thesis. Our method is applied when the practical part of the thesis project is done, and the student starts to write the thesis paper. As our experience shows, at this stage he/she very often fails to give a clear explanation of the thesis goals, with only the supervisor being able to explain the choice of the topic, the use of particular technologies, etc. Undergraduates tend to view the thesis statement as a set of requirements to fulfill, instead of an issue to contemplate and discuss. The first step is thus intended to raise their awareness of the thesis goals. When they start writing their text seems the most suitable time to reconsider this information. We recommend compiling a list of thesis goals.

Specifying the results. It is not very easy for undergraduates to identify the results of their work. What exactly has been done? An algorithm, software architecture, software, experiments? It does not mean the student has produced nothing. Often it means they need help to identify various work products. Sometimes, some of these products require additional work, such as appropriate testing and evaluation of the software developed. All these work products will be thesis results, and it takes some effort and time to specify them. Ideally, thesis results should be presented as a list, with each item of the list having a brief description of the corresponding work product. We normally recommend our students to include this list in the conclusions section. It is also important that the goals correlate to the results.

Creating paper backbone. The main purpose of the thesis paper is to present and describe the results of the thesis project. At the previous steps, the student defines the goals and specifies the results of the thesis. We recommend to map every result (thesis work product) to a separate chapter of the thesis paper. The set of chapters and their subsections are specified on the thesis mind map. Additional chapters are Background and Related Work, which are also specified on the mind map. In case of industrial theses, Related Work means a description of existing software solutions similar to the one developed by the student in the thesis project.

Planning and writing the introduction. This is important as a special step because the introduction commonly poses a serious challenge to many students, as it has to include a brief description of thesis contexts and involved fields, and a clear setting of the goals. The plan of introduction is developed in the mind map for an easier discussion with the course lecturer.

Writing & discussing first paper drafts. It is important to transfer the mind map correctly into the first draft of the thesis paper. This has to be assisted because this is a stage when many errors are spotted and corrected, and misunderstandings are clarified. Moreover, students sometimes start writing their thesis papers neglecting the plan they developed before. Writing the first drafts helps to avoid this, the draft serving as a guarantee that the students will continue their work by following initial developed plans.

5 COURSE

The method is implemented as a semester course. The course is mandatory for all last year undergraduates

of our department. It is held in the last semester when our students work on their theses. The flowchart of the course is presented in Fig. 4. Let us now consider the course in more detail.
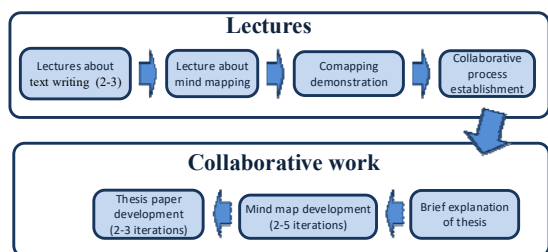

Figure 4: Flowchart of the course.

Lectures about text writing. These lectures ensure that students understand the role of text in thesis development and become familiar with the recommended patterns and guidelines.

Lecture about mind mapping. Students learn about mind mapping and other types of information visualization techniques (Kudryavtsev, Gavrilova, Leshcheva, 2013), about knowledge management (Gavrilova, 2010) and the features of mind mapping.

Comapping demonstration. Since this software is simple and ergonomic, a demonstration of its main features is sufficient for the students to learn to use it.

Collaboration process establishment. The process of collaboration is explained and agreed on with the students. They are also given access to Comapping.

The next steps are conducted as one-to-one sessions of the course lecturer and the course student. One or two members of the department staff help the course lecturer. It should be noted that mind mapping allows to spend 10-15 minutes per student to verify and discuss the current version of the thesis plan. Often the lecturer and his/her assistants verify mind maps before class to save time.

Brief explanation of thesis. The course lecturer/assistant is not supposed to go deeply into the details of each thesis because it would take too much effort and time. However, he/she needs to have a clear idea of each thesis in order to be able to provide appropriate recommendations. With most theses, it does not pose much difficulty as they are supervised by the department's industrial partners or by the department staff, so the course lecturer is already familiar with the topic areas. There can be a few theses on topics from new industrial companies or from staff from other university departments, in that case understanding their ideas may be less easy for the course lecturer.

Mind map development. Every course student creates a plan for his/her paper under the course lecturer's/assistant's supervision. It usually takes 2 to 5 iterations, depending on how intensively the student works. Ideally, after the first iteration, the student discusses the plan with his/her supervisor and then corrects it.

Thesis paper development. Two or three iterations are optimal for the purpose. The first iteration normally reveals certain problems (for example, the plan turns out to be inadequate and the student has to go a step back to improve it). The following one or two iterations give the students a chance to correct the found errors. This step is the most labor intensive for the course lecturer and assistants, because they need to read a large number of papers. However, it should be noted that these papers contain only the introduction (with thesis goals), conclusions (with results), and the thesis contents page. Thus, it is quite easy to read them. It is a challenge, though, to organize the course work, i.e. to avoid the situation when most students submit their papers at the same time at the end of the course, which causes the course lecturer and assistants to overwork.

6 EVALUATION

We have delivered this course for the past 7 years, with more than 300 students having taken it so far. We have studied the department's thesis papers of the last 10 years and witnessed a considerable improvement in their quality. We believe that the course presented here made a significant contribution to this progress.

In addition, we conducted an evaluation of the method and the course. We prepared a sample selection of papers, developed both with and without the course assistance. We then asked several independent experts, who did not know about the course, to estimate the quality of the papers. Our hypothesis was that the course assisted papers would be found by the experts to be of a higher quality. Below we describe the evaluation in more detail.

We selected 4 papers which had been assisted by the course and another 4 papers which had been written without the course assistance. For every paper we removed all the information about the author and the supervisor.

We developed a questionnaire for experts to evaluate paper quality. The questionnaire contains the following questions:

1. What is your level of competence in the subject area?
2. How would you characterize the degree of the paper's complexity?

3. Is the topic easy to understand?
4. Can the thesis goals be easily understood?
5. Are the motivation and relevance of the paper clear?
6. Is it easy to see what exactly has been done by the student (i.e. the results)?
7. Is it possible to judge how profound the results are?
8. How comprehensive is the description of the results?
9. What degree of text integrity does the paper demonstrate?
10. Is the paper free from unnecessary details?
11. Does the structure of the paper help to gain an insight into the matter?
12. Is it written in good Russian/English?
13. Is text formatting good enough?
14. How appropriate is the use of special terminology?
15. Would you recommend this text to anyone?

We used a five-point Likert-type scale which ranges from "excellent" to "very bad".

We found 10 external experts to read and evaluate the papers. Six experts had an industrial background (managers and software developers), while four had an academic background. The results of the survey are presented in Table 1.

Table 1: Evaluation results.

Course assisted	course unassisted
4,8	3,3
4,7	3,6
4,6	3,8
4,7	4,1
4,7	3,7

The first column contains the total scores for thesis papers that had been assisted by the course. The second column contains the total scores for the unassisted papers. For every paper, the total score was calculated as the average of scores for each question (except the first two). The bottom row of the table shows the average scores for course assisted and course unassisted papers.

The data in Table 1 confirms our hypothesis: course assisted papers scored the average of 4.7, while course unassisted papers – only 3.7.

It should be noted that the industrial background experts tended to generally like or dislike the papers rather than to be scrupulous, and evaluated the papers accordingly. This resulted in a wide scatter in the grades they gave. The representatives of the academia were more precise and rigorous in the assessment. A

more extensive evaluation remains a task for the future.

7 CONCLUSIONS

The current paper presents a method for the management of thesis writing for software engineering undergraduates. The method is based on mind mapping for the early design and discussion of the thesis paper plan. It is implemented as a one semester course for last year undergraduates. The evaluation conducted indicates a significant increase in the quality of thesis papers.

One aspect for further research could be the use of thesis mind maps for peer student reviews or other kinds of reviews. It can prove beneficial as thesis mind maps appear much earlier than papers. Also, mind maps are easier to review, and corrections can be done faster.

It should be noted that the method and the course are suitable for both undergraduate and graduate students, and can be applied not only in software engineering, but also in many other education fields. The method can be modified depending on the particular requirements. Graduate students, for example, need a more academic, research-based focus. Other education fields may offer various other thesis paper templates. What is important is that the core of the method suits any student specialization. Some preliminary steps to adapt the method to courses in design and business education fields have already been taken.

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