

## **Using Scrum for Managing Master Theses - A Case Study**

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# Abstract

The success rates of the master's theses in Instituto Superior Técnico's Master in Information Systems and Computer Engineering are very unsatisfactory and in the last five years, less than half of the students have completed this work in their first enrollment, but the success rates of a group of students that were supervised based on the Scrum framework are very promising.

Using the Case Study Research Methodology, we aim to study the current situation and explore if the use of Scrum to manage master's theses increases the probability of successfully complete a work of this nature and the benefits it brings to students. To obtain new insights, we used interviews to collect opinions and experiences of students that were oriented based on this framework.

To understand how Scrum can address existing problems in the guidance and development of master's theses, and which practices and benefits were present according to students, we performed a qualitative analysis and discuss the obtained results. We also discuss the practices and benefits of previous studies focused on the accomplishment of projects to understand which practices have a relation to the success in the development of a master's thesis.

## Keywords

Scrum; Master's theses; Management of theses; Success rate



# Resumo

As taxas de sucesso das dissertações do Mestrado em Engenharia Informática e de Computadores do Instituto Superior Técnico são muito insatisfatórias e nos últimos cinco anos, menos de metade dos alunos concluíram este trabalho na primeira inscrição da unidade curricular da dissertação, mas as taxas de sucesso de um grupo dos alunos que foram supervisionados com base na *framework* Scrum são muito promissoras.

Usando a Metodologia de Pesquisa do Estudo de Caso, pretendemos estudar a situação atual e explorar se o uso do Scrum para gerir teses de mestrado aumenta a probabilidade de concluir com sucesso um trabalho desta natureza e os benefícios que o Scrum traz para os alunos. Para obter novos conhecimentos e perceções, usamos entrevistas para recolher opiniões e experiências de alunos que foram orientados com base nesta *framework*.

Para entender como o Scrum pode solucionar os problemas existentes na orientação e desenvolvimento de teses de mestrado e quais as práticas e benefícios que estavam presentes de acordo com os alunos, realizamos uma análise qualitativa e discutimos os resultados obtidos. Discutimos também as práticas e benefícios de estudos prévios com foco na realização de projetos para entender quais as práticas têm uma relação com o sucesso no desenvolvimento de uma tese de mestrado.

## Palavras Chave

Scrum; Teses de mestrado; Gestão de teses; Taxa de sucesso





# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Research Question . . . . .	2
1.2	Thesis Outline . . . . .	3
<b>2</b>	<b>Related Work</b>	<b>4</b>
2.1	Scrum . . . . .	4
2.2	SCORE: Adapting Scrum to managing a research group . . . . .	6
2.3	Scrum in Courses . . . . .	7
2.4	Benefits and Advantages of Scrum . . . . .	10
<b>3</b>	<b>Research Methodology</b>	<b>13</b>
3.1	Data Gathering Techniques . . . . .	14
3.1.1	Interviews . . . . .	15
3.1.2	Cognitive Mapping . . . . .	16
<b>4</b>	<b>Results and Analysis</b>	<b>18</b>
4.1	Interviews . . . . .	19
4.1.1	Previous Knowledge . . . . .	20
4.1.2	Expectations . . . . .	22
4.1.3	Elements of Scrum present in the context of the thesis . . . . .	22
4.1.4	What is the most important element? . . . . .	26
4.1.5	Meetings . . . . .	29
4.1.6	What were the perceived benefits? . . . . .	30
4.1.7	What were the perceived disadvantages? . . . . .	35
4.2	Cognitive Mapping . . . . .	38
4.2.1	Domain Analysis . . . . .	43
4.2.2	Central Analysis . . . . .	44
<b>5</b>	<b>Discussion of Results</b>	<b>47</b>
<b>6</b>	<b>Conclusion</b>	<b>52</b>
6.1	Communication . . . . .	52
6.2	Limitations . . . . .	53
6.3	Future Work . . . . .	53
<b>A</b>	<b>Interview Guide</b>	<b>59</b>



# List of Figures

2.1 Scrum Process . . . . .	5
3.1 Case Study Research process model (taken from [1]) . . . . .	14
4.1 Coding process (adapted from [2]) . . . . .	18
4.2 Final Cognitive Map drawn from interviews with interviewees of the 2012/2013 academic year . . . . .	41
B.1 Final Cognitive Map drawn from interviews with interviewees of the 2009/2010 academic year . . . . .	61
B.2 Final Cognitive Map drawn from interviews with interviewees of the 2010/2011 academic year . . . . .	62
B.3 Final Cognitive Map drawn from interviews with interviewees of the 2011/2012 academic year . . . . .	62
B.4 Final Cognitive Map drawn from interviews with interviewees of the 2013/2014 academic year . . . . .	63
B.5 Final Cognitive Map drawn from interviews with interviewees of the 2014/2015 academic year . . . . .	63
B.6 Final Cognitive Map drawn from interviews with interviewees of the 2016/2017 academic year . . . . .	64
B.7 Final Cognitive Map drawn from interviews with interviewees of the 2017/2018 academic year . . . . .	64



# List of Tables

1.1	Information about the number of students enrolled in the master's thesis and the success rates in five academic years . . . . .	2
4.1	Number of students interviewed by academic year . . . . .	19
4.2	Prior knowledge of Scrum of the interviewees . . . . .	20
4.3	Elements of Scrum applied according to interviewees during the development of their master's thesis . . . . .	25
4.4	Most important elements of Scrum applied according to interviewees for the development of a master's thesis . . . . .	28
4.5	Five benefits of Scrum that were most referenced by interviewees . . . . .	34
4.6	Opinions of interviewees concerning the effect of pressure . . . . .	36
4.7	Domain analysis of the concepts of the several cognitive maps . . . . .	43
4.8	Five most central concepts of each cognitive map . . . . .	45
6.1	Papers accepted and submitted under the scope of this thesis . . . . .	53



# Acronyms

**CSRM** Case Study Research Methodology

**NEP** Statistics and Prospective Unit

**SAFe** Scaled Agile Framework

**SCORE** Scrum for Research





# 1. Introduction

Almost every master's program ends with a master's thesis. A master's thesis is an autonomous piece of academic work, and for the majority of students undertaking this assignment will be the first-time doing a work of this nature and complexity.

Within the Master program in Information Systems and Computer Engineering of Instituto Superior Técnico, the values for the success rate (or completion rate) of finishing a master's thesis work, that is, the percentage of students approved on the first enrollment has been increasing. For example, in the 2012/2013 academic year, the percentage of students' approval at the first enrollment in the master's thesis in a specific faculty's campuses was just 30%, but in the 2016/2017 academic year, the percentage on the same campus was 49%, which is still an unsatisfactory value.

Since the 2012/2013 academic year, studies and inquiries have been developed by the Statistics and Prospective Unit (NEP) to determinate the reasons that contribute to the existence of very unsatisfactory completion rates and the longer (than stipulated) average time of theses completion. In these studies, several students were surveyed to measure their satisfaction with the development process of the master's thesis. In the Master in Information Systems and Computer Engineering, among students who evaluated their orientation as unsatisfactory, the main reasons that led to dissatisfaction with the development process of the master's theses were threefold: lack of commitment and limited time of the supervision team to monitor the work, insufficient knowledge transmission capacity, and lack of support for experimental work development.

Another issue regarding student's projects exposed by Hans, and Kudikyala and Dulhare is that *"the quality of the final products of the students' projects has by and large been declining over the past few years. Furthermore, the student's poorly completed projects are either late or are not delivered at all on the due dates"* [3] [4] [5]. The use of Scrum can be a strategy in order for projects to be carried out in an iterative manner, that would prevent students to wait for the final moments to work on them [3] [4]. This strategy follows the general approach used in the application of the Scrum framework for software development.

According to Sutherland and Schwaber, Scrum is a *"framework within which people can address complex adaptive problems, while productively and creatively delivering products of the highest possible values"* [6]. Scrum was initially thought to handle software development projects in enterprises, but since the results of applying this to software development are very positive, Scrum has been used in other settings [7].

Scrum focus on project management and can be a mechanism to handle complex projects with unpredictable settings, where the scope of a project may not be well defined and to minimize the risks associated with a project, therefore Scrum can help us to address uncertainty and to respond to changes and provide a set of rules and guidelines to be more productive [6].

Regarding the success rates of a group of students who were oriented and managed based on the Scrum methodology and the agile practices, these are very high compared to the rates presented in the studies done by NEP<sup>1</sup>. In Table 1.1, it is presented the number of students enrolled in the master's thesis work on both college campuses, the completion rates of the students who finished their master's thesis at the first enrollment in each campus and the completion rate of students that were guided based on Scrum during the development of their master's thesis in five academic years.

**Table 1.1:** Information about the number of students enrolled in the master's thesis and the success rates in five academic years

	Academic Year				
	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017
Number of Students enrolled in Master Thesis (Campus Alameda)	116	110	148	151	146
Success Rate Campus Alameda	30%	48%	43%	55%	49%
Number of Students enrolled in Master Thesis (Campus Taguspark)	79	80	94	90	98
Success Rate Campus Taguspark	32%	48%	41%	54%	29%
Success Rate of Students Managed with Scrum	100%	80%	100%	100%	90%

## 1.1 Research Question

Given that the success rates for master's thesis are unsatisfactory and given that the success rates of the master's theses that were managed based on the Scrum framework, as can be seen and compared in Table 1.1, our research question is: **does the use of Scrum in the management process in the development of master's theses increase the probability of successfully complete a master thesis?**

In order to perceive how Scrum can help in guiding and managing students during the development of their master's thesis, our target audience or cases, were students who are, or have been, oriented with the Scrum methodology, since their experience and their understanding of this problem is key to draw conclusions about the use of Scrum in this specific context.

We also wanted to analyze and explore which good practices of the agile methodologies were present during the development of the master's thesis according to the students' opinion, their relation to the success of the master's thesis, and if Scrum can be a mechanism that helps to minimize the problems already presented in this document.

<sup>1</sup> Studies regarding the success rates of master theses can be found at <http://quc.tecnico.ulisboa.pt/en/dissertacoes/>

## **1.2 Thesis Outline**

This document is structured in the following way. In Chapter 2 it is presented the Related Work relevant to this research, including previous studies that are of interest in the context of our research. In Chapter 3 it is clarified the Research Methodology and the steps followed in the context of this thesis and we explained which Data Gathering Techniques were used, in the context of the Research Methodology, to collect data. The Results obtained are presented and analyzed in Chapter 4 and discussed in Chapter 5. Finally, in Chapter 6 we present the final conclusions, communication, research limitations, and future work.

## 2. Related Work

In this Chapter we present a literature review of the topics related to this research. We start by presenting the theoretical background of Scrum, that is, the roles, meetings, and artifacts that composed Scrum. Next, we present studies that address the application of Scrum in academic contexts, such as the management of a research group and in the development of courses projects. In this Chapter we also address studies that focuses on the benefits, advantages, limitations of Scrum and the relation of this framework with the success of projects.

### 2.1 Scrum

Scrum was proposed as a more effective and agile way to develop software projects and as an alternative to other methodologies such as Waterfall, where a project is planned in the beginning and completed in different stages until it is released to its customers [7]. Most times, the clients never received the product that they wanted [7].

Scrum is based on the following idea *"Whenever you start a project, why not regularly check in, see if what you're doing is heading in the right direction and if it's actually what people want?"* [7]. Scrum is based on empirical processes, that is, it is based on the assumption that it is difficult to predict and plan a project from the beginning to the end.

The approach used in Scrum to plan and manage work is through iterations lasting between two and four weeks. These iterations are known as Sprints and that's where the planned work is developed and where the meetings associated with Scrum take place. Sprints are made consecutively and it allows the development of work in an iterative and incremental approach until a product is ready to be delivered. When a Sprint ends, the following Sprint begins immediately.

In order to plan and manage work with Scrum it is very common to use a Product and Sprint Backlog. The Product Backlog is a list that contains everything that needs to be done in a project life cycle. At the beginning of a project, this list does not need to be complete. Over time the Product Backlog grows and changes as stakeholders learn more about the project and what should be done in the context of that project. Sprint Backlog is constituted by some items selected from the Product Backlog to be done in a Sprint.

In Scrum, there are three roles which are the Product Owner, Scrum Master and the Team. The Product Owner is responsible for managing the Product Backlog and update it with items to be developed in the context of a project. The Scrum Master is responsible for ensuring that Scrum is being practiced

by the Team. The Scrum Master also helps in eliminating anything that is delaying the work of the Team. The Team is responsible for delivering the work present in the Sprint Backlog. The people who play and constitute these roles, form the Scrum Team.

In the context of Sprints, there are several meetings. The Sprint Planning meeting can be divided into two parts, one part where it is discussed what can be done in a Sprint and another where the work to be performed in a Sprint is planned and discussed between project stakeholders. This meeting represents the beginning of a Sprint cycle.

The Sprint Review meeting is where it is reviewed the work done in a Sprint considering what was present in the Sprint Backlog to understand if the planned work has been done and if any work increment has to be improved in the next sprint. In this meeting, it is also updated the Product Backlog regarding the priority of the items present in this list.

The Sprint Retrospective meeting is where the Scrum Team discuss what went well and wrong in order to create improvements to apply in the next Sprint. These meetings generally occur separately, but the Sprint Review and Retrospective meetings may occur on the same day, signaling the end of a Sprint cycle.

The Daily Scrum meeting is a fifteen-minute meeting held every day, where the Scrum Team discusses the progress of the work to be delivered at the end of the current Sprint and identify obstacles that prevent the work from being carried out.

Figure 2.1 presents a summarization of the Scrum process composed by the Scrum roles, meetings, and artifacts.

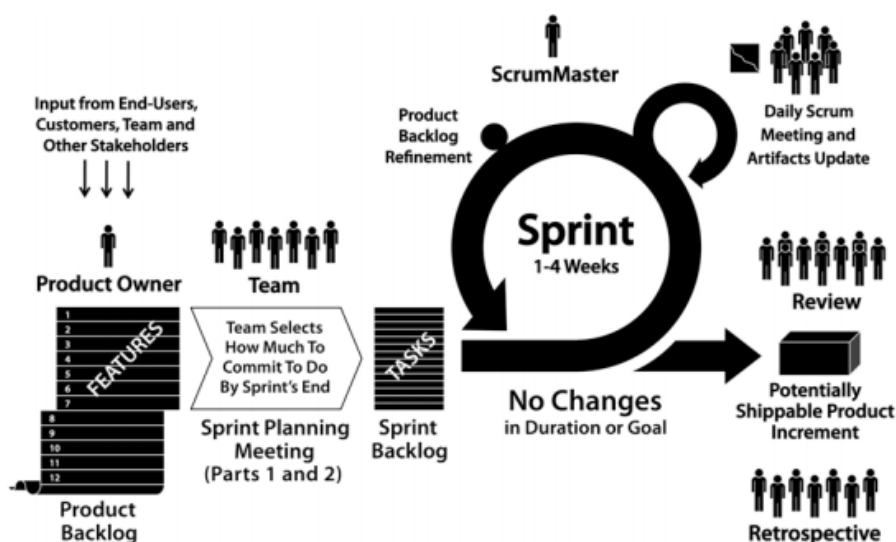


Figure 2.1: Scrum Process

## 2.2 SCORE: Adapting Scrum to managing a research group

In [8] [9], it is presented an adaptation of Scrum, called Scrum for Research (SCORE), to manage students in the context of a research group. Before adopting Scrum, the authors follow a simple way to mentor their students. The authors meet each student once or twice a week. The number of students mentored and few commitments allowed to the authors to follow this process. But the number of students mentored by Hicks and Foster increased, such as external commitments, which affected their schedule. This also affected the frequency and the quality of the meetings, which meant that the students' doubts were not addressed when they emerged and that the research carried out was not followed properly by Hicks and Foster to provide feedback and guidance. To respond to these problems, they decided to adopt SCORE into their research group.

In SCORE, Hicks and Foster hold three times a week status meetings in which each student has fifteen minutes to report his or her progress, the difficulties that have arisen and plan the next work to be carried out [8] [9]. This meeting is the core of SCORE and corresponds to the daily meetings in Scrum.

Hicks and Foster decided not to hold status meetings on a daily basis because the members of the research group felt there was no need to hold a meeting every day [8] [9]. If the students need to discuss technical issues or need more time to expose their work or difficulties, it is schedule an on-demand meeting. Generally, Hicks and Foster schedule these meetings based on the issues that emerge in the status meeting.

The introduction of SCORE in the research group has brought some benefits to Hicks and Foster such as knowing when students are struggling and address issues as soon as possible and keep track on students' work and progress. This has increased their productivity because these meetings have a clear purpose for them and are separated in order to address specific situations. It also allowed for a more efficient time management since status meetings are short-lived and on-demand meetings are only held when needed.

Another benefit originated by the status meeting is to provide each student with a vision of the work of their peers to understand the difficulties of each and what went well in the work of each one in order to improve their own work. Other aspect of SCORE, that the authors try to foster is to gather the students in the same workplace to improve communication between them.

In [8], Hicks and Foster present the opinion of the students regarding this method (gathered through a survey). Students claim that they are more productive, have better interactions with their supervisor, and regular meetings create a work pace but with these meetings can be hard to schedule other things outside the research group work.

The application of SCORE with the proposed elements is successful when all the elements of the team are present in the same place of work. For example, in the case of master's theses we are

addressing, several students are doing several courses and this is something that makes it difficult for them to be present in the same workplace as their supervisor. This also leads to students not being able to work every day in their thesis, which would also lead to the loss of importance of status meetings, since sometimes students may have nothing to report.

## 2.3 Scrum in Courses

In the literature, there can be found many papers regarding the application and introduction of Scrum in student courses. Previous experiences with Scrum in student projects were also performed and predominantly successful, and that knowledge can be meaningful for this study.

For instance Wallace et al. states that Scrum it is not only a software development strategy, but is a general learning strategy, since it *"also describe the student learning environment: complexity (new and unfamiliar concepts), under-defined problem space (students don't know what they don't know), short timeframe with frequent meetings (terms and class meetings), and inevitable change (apply new knowledge)"* [5].

Wallace et al. exposes how students learn and practice Scrum, how it can be used to manage student projects, and the effects of the adoption of Scrum. With the short two-week iterations, the engagement with a client, and frequent demonstrations provide structure and motivation that helps students in completing their projects. Short iterations and constant feedback from clients also help students to develop projects with higher quality, since there is an exchange of ideas with a client in order to deliver something that is truly desired [5].

Other aspect presented is the discussion of the project's progress with an instructor on a frequent basis and the identification and validation of the next steps to be performed by students and that will be discussed in the next meeting between these two parties. In [5] it is also stressed out the importance on the reflection (or retrospective). These authors noted that looking *"back and consider the lessons learned from prior experience"* allows students to refine their work and reapply what they learn in order to improve their work and to improve their experience in concrete Scrum aspects, such as, developing *"an understanding of the issues involved in estimating"* [5].

Another example is the research conducted by Rover et al., in which it is presented a case study on a capstone design project where it was used agile project management, similar to Scrum with Sprints and meetings held between the students, a faculty member, and a client to manage the development of a product [10].

At the end of each Sprint, the students released new features and fixes in order present a deliverable of a subset of the final product. Sprints also made the customer involved in the product development in order to guide each Sprint's work and inform the features requests and goals for the next Sprint at each Sprint meeting. In [10] it is exposed that the client always knew what the team was doing, if they had

issues, and that in addition to the meetings, they also communicate with the students by email in order to solve the problems that were emerging.

According to Rover et al. Sprints and meetings between these students, faculty member, and clients foster communication, which led to obtaining frequent feedback from the customer and determining what items added value to the customer that could be made in Sprints. It is also added that the iterative development applied, made planning more tractable, react quickly to unexpected situations, and that a working product would be delivered to the customer, since Sprints made students more accountable, motivated, and responsible. The major outcomes or benefits originated by these agile practices exposed by Rover et al. were teamwork, product quality, customer focus, and iterative development [10].

Mahnic and Rozanc designed their course to teach how Scrum is used in the real-world environments, in order to help their students to understand the issues and to improve their skills regarding the utilization of Scrum. They reported that a capstone course is a opportune place for the introduction of this method and to simulate it in a real-world experience in order to consolidate this knowledge [11]. In this course Mahnic and Rozanc exposed that first it was introduced the concepts and principles of agile, Scrum, Product Backlog, and iteration planning in a preparatory Sprint. Following this introductory Sprint, students were given the Product Backlog which contains the items that will be developed in the context of the course project, that could be discussed with their Product Owner. At the end of each sprint, the review and retrospective take place with a course instructor. In these meeting the students present the work developed in that Sprint and review the work done in order to receive feedback and suggestions for improvements for the next Sprint [11].

After finishing the project, students were asked to evaluate in a survey the practices of Scrum that contribute to the success of a project, which were compared to the Scrum practices that were perceived as more important for the success of software projects by professional developers in order to understand similarities and differences between the point of view of both parties. Since Mahnic and Rozanc wanted to compare students' opinions with opinions of professionals, the same survey was also conducted among six developers. In order to identify the most important success factors, practices were rated in a 5-point Likert Scale. The practices rated were: quality of requirements specified in Product Backlog, good communication with the Product Owner, good Scrum Master, team-work and communication among team members, accurate user story estimations, release planning, Sprint Planning meeting and maintenance of the Sprint Backlog, Daily Scrum meetings, Concept "done", Sprint Review meetings and Sprint Retrospective meetings.

According to Mahnic and Rozanc both parties agree that factors such as communication with team members and the Product Owner were the most important for a project to succeed [11]. Students and professionals had similar opinions regarding the role of the Scrum Master, the importance of the Sprint Review and Retrospective meetings and having a clear concept of "Done".



On the other hand, these two parties did not share their opinions regarding the importance of Sprint Planning (highly rated by professionals) and the clarity of the requirements present in the Product Backlog (highly rated by students). Mahnic and Rozanc also exposed that this derives from the fact that developers are aware that the Sprint Planning leads to a more concise Sprint Backlog and therefore a more smooth Sprint and because students felt that precise user stories were enough to reach the desired results and if some user story is not precise, the Product Owner was available to explain what was expected [11].

Pope-Ruark adapted Scrum to structure group projects and to manage student collaboration. Students were introduced to Scrum and their projects in classes. Scrum was used to manage the work and Pope-Ruark served as project manager and mentor in order to help students define and achieve goals in the context of their projects [12].

Pope-Ruark exposed that the Scrum framework is a roadmap for students to develop and finish their projects [12]. In order to evaluate the progress of this roadmap, Pope-Ruark held Daily Scrum meetings, in which students could report the work done. In this meeting all students answer the following questions [12]:

- What have I done since we last met?
- What will I do today?
- What challenges might I face or need assistance with?

Based on these questions students can ask what they want in order to discuss the subjects of their interest with the instructor and all colleagues. Pope-Ruark states that a successful and good implementation of Scrum in a course demands that *"instructors must also completely commit to the process and be very patient once the project is launched. The instructor must be constantly aware of potential teaching moments, constantly thinking of potential readings or discussion topics to help the students"* [12]. Other aspect exposed is that *"Scrum works best for complex group projects that have some large end product"* [12] in order to develop the work through small increments, which lead to achieving the final goal or product and that Scrum projects encourages students to be more accountable and to engage in this kind of projects, that follow an agile paradigm.

In this Section, we presented some works regarding the application of Scrum in courses group projects. Despite the fact that our work focus on the application of Scrum to manage master thesis, which are developed by a student and therefore are works of an individual nature, the teachings regarding which parts of Scrum were applied, how students felt with the practice of Scrum, what are the roles that instructors can perform, what components of Scrum are more important and helpful according to instructors and students are valuable for this work, since some the problems faced by student in group

projects are the same in works of an individual nature and master thesis in particular, as was exposed previously in Chapter 1.

Some of the issues to addressed and exposed in these works were: students' *"projects were typically not completed by the end of the semester"* [5], improve the students' performance, product quality, and client satisfaction [10], improve the collaboration between students and engage them in group projects [12]. In order to minimize these issues, the strategy used by these authors was the adoption of Scrum, that resulted in positive results, as exposed in this Section.

## 2.4 Benefits and Advantages of Scrum

The works presented in the previous Section also address the benefits and advantages that Scrum can bring in an academic context, but the focus of these works was on the application of Scrum in an academic context. In this Section we are going to address researches that focuses on the benefits of the adoption of Scrum and the agile methodologies and the relation between them and the success of projects.

The research developed by Mariz, França and Silva aimed at investigating the relationship between the use of agile practices and the success of projects that use Scrum [13]. To approach this, these investigators conducted a cross-sectional survey that collected data from sixty-two professionals that worked on Scrum projects and who performed the roles of Scrum Master and members of the Team, which were presented in Section 2.1. These professionals evaluated the relation between the success of projects and twenty-five agile practices defined by Chow and Cao [14]. These agile practices are encompassed in the following six factors: deliver strategy, agile software engineering techniques, team capability, project management process, Team environment, and customer involvement.

According to the results obtained in their research, Mariz, Franca and Silva state that eight of the twenty-five practices presented by Chow and Cao are highly correlated with the success of projects, in which Scrum was used [13]. These eight practices are: regular delivery of software; correct integration testing; delivering most important features first; team members with high competence and expertise; following agile-oriented requirement management process; following agile-oriented configuration management process; coherent, self-organizing teamwork; good customer relationship. Mariz, Franca and Silva also noted that two of these eight practices present a higher correlation to the success of a Scrum project. These two practices are Regular delivery of software and Correct integration testing. Regarding the other thirteen practices present in [14], Mariz, Franca and Silva exposed that these did not presented a significant degree of correlation that to justify that they would have a relation or effect in the success of projects [13].

In the work developed by Solinski and Petersen it is recognized the significant benefits and limitations that originate in the adoption of agile and which practices are commonly used by practitioners of agile

methodologies in order to prioritize these benefits and limitations regarding its usage in practice in certain categories [15]. The research described in [15] is an exploratory study and the data was collected through an on-line questionnaire, in order to capture the practices used and their importance according to practitioners to prioritizing a list of benefits and limitations (based on the literature).

In their research Solinski and Petersen also distinguish benefits in two types, which are external benefits and internal benefits. External benefits refer to the outcomes relevant to a client and internal benefits are related to the agile process used.

Regarding the results obtained in [15], the categories perceived as more beneficial to the Scrum process are knowledge and sharing, and feedback and confidence. The benefits associated with these categories are: improved communication, common understanding (of a problem), early verification design decisions increase awareness of what has to be developed, and early requirements validation. Solinski and Petersen also add that *"agile makes people feel purposeful, improves knowledge transfer and learning between team members, leads to early requirements validation due to frequent feedback, and improves turn-around time for fixing bugs"* [15].

Regarding the main limitations of the practice of agile methodologies according to Solinski and Petersen these are scalability (applying agile to larger teams, of ten people for example) and professional skills specific demands (agile requires sufficiently trained managers). In [15] it is also added *"that practitioners should invest in training on agile in order to make the adoption work effectively"*, since *"it is apparent that lack of knowledge on agile methods is one most significant obstacles on the way to effective agile processes"*.

Begel and Nagappan conducted a research on agile development in an industrial context. In their work, they ask the participants in a web-based survey, which agile practices they used in their work and what are the top ten benefits of agile were in order to form a ranking of common benefits [16]. The top three benefits gathered by the work of Begel and Nagappan are improved communication and coordination, quick releases and flexibility of design (quicker response to changes).

In [16] it is noted that Scrum meetings are instrumental to gather all parties of a project together in order to have an overall better communication, to improve awareness of team member's activities, and discover problems in earlier stages of projects. Quick releases lead to demonstrations of releases in a weekly basis, instead of a monthly or yearly basis. This also makes easier to keep track of the progress of the project, monitor its quality, provide feedback to improve the project, and improves turnaround time for fixes. Regarding flexibility of design, Begel and Nagappan expose that *"short sprints combined with more emphasis on customer feedback led to better agility and efficiency in responding to changing requirements, internal processes, reorganizations or politics, and flushed out bad designs more quickly"* [16]. Flexibility is not solely based on the product, but it also refers to the agile development process, since this permits changing the direction of work, embraces change, and it allows flexible iterations.

The other benefits present in [16] are: more reasonable process, increased quality, better customer focus, better prioritization, increased productivity, better morale, and testing first. Despite the focus of [16] was to form a ranking of common benefits, Begal and Nagappan also present ten problems of agile development perceived by the participants. These problems include: scalability, too many meetings, lack of knowledge regarding agile methodologies, coordination with other teams, and the lack of a fixed and predictable schedule.

In this Section, we presented some research regarding the benefits and limitations that may arise from an application of the Scrum framework and the agile methodologies. The research presented also focuses on the relation of the success of projects and the benefits derived from the agile practices. This knowledge is very important for this work since it is closely related to our research question, and therefore it is interesting to explore which agile and Scrum practices have a correlation to success in order to understand which practices should be adopted.

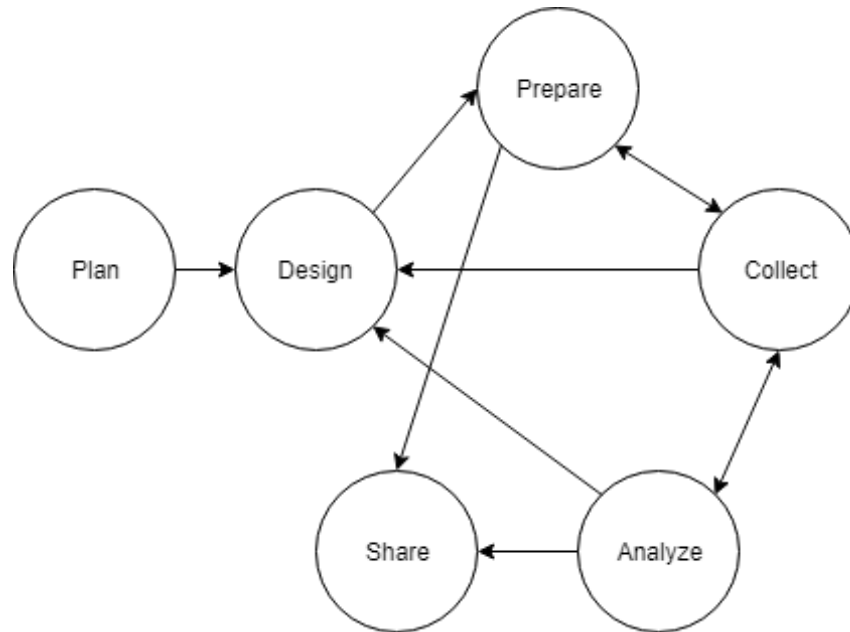
### 3. Research Methodology

The approach chosen to guide this work was the Case Study Research Methodology (CSRM). This methodology is defined by Yin as an *"empirical inquiry that investigates a contemporary phenomenon within its real-life context"* [1]. This approach was chosen to make the best of the experience held by the participants and profit from their understanding of the adoption of Scrum in the development of a master's thesis, since it is key to draw conclusions about the use of this project management method in this specific context. *"Through case studies, researchers hope to gain in-depth understanding of situations and meaning for those involved"* [17]. This methodology is characterized by the examination of several people, experimental controls are not required [18], and the behavior of the participants is not manipulated [19].

CSRM is composed by six steps proposed by Yin [1]:

1. **Determine and define the research questions:** In this methodology, one or more questions can be done to provide answers to How and Why questions and it is determined the purpose of the study and also the planning of the study.
2. **Select the cases and determine data gathering and analyses techniques:** The researcher must decide the unit of analysis of the study, that is, selecting between single and multiple case study. To select the unit of analysis, the researcher can review the purpose of the study, which cases can provide information to answer the research questions. Regarding the information, the research must choose in advance how this will be gathered and analyzed.
3. **Prepare to collect data:** In this stage, the researcher can develop a case study protocol that contains information about the case study, interview guides and questionnaires to ensure that the questions made to the participants are the same, and a template mail to invite the participants.
4. **Collect data in the field:** The researcher collects data from multiple sources to answer the research questions.
5. **Evaluate and analyze the data:** After finishing collecting the required information, the researcher depending on the type of data gathered and the techniques chosen previously, explore the data collected to find evidence to answer the original research questions.
6. **Prepare the report:** Once the case study is completed, the researcher documents, shares and communicates his or her findings.

The numbered steps correspond respectively to the phases Plan, Design, Prepare, Collect, Analyze and Share of the process model presented in Figure 3.1.



**Figure 3.1:** Case Study Research process model (taken from [1])

Another motive regarding the use of this methodology was due to the fact that there is insufficient information in the literature regarding the adoption of Scrum in this more specific academic context, that is, the development and guidance of master's theses. The CSRM is appropriate in these cases, whenever there is little evidence regarding a topic in the literature, since this methodology is suitable to *"find out what is happening, seeking new insights and generating ideas"* [2], therefore our Case Study followed an exploratory purpose within a qualitative approach.

### 3.1 Data Gathering Techniques

This Section corresponds to the Design step of the CSRM and where we present the data gathering and analyses techniques used in this thesis.

In order to obtain an insight about the utilization of Scrum in the context of a master theses, the main research object of analysis are students doing their master's theses using the Scrum framework and former master degree students, who made their theses also using Scrum. Since the unit of analysis of this study is composed of several people, this case study is a multiple case study.

### 3.1.1 Interviews

Interviews are a qualitative method to collect data which is widely used in Case Study Research to *"provide in-depth information pertaining to participants' experiences and viewpoints of a particular topic"* [20] because *"Case Studies tend mostly to be based on qualitative data, as these provide a richer and deeper description"* [2].

Interviews are based on the communication between two (single interviews) or more (group interviews) people, therefore in an interview there could be a lot of interactions. *"Individual interviews yield significant amounts of information from an individual's perspective, but may be quite time-consuming. Group interviews capitalize on the sharing and creation of new ideas that sometimes would not occur if the participants were interviewed individually; however, group interviews run the risk of not fully capturing all participants' viewpoints"* [17].

Individual interviews were chosen to be used in this work based on what has been previously exposed and because the data collected by this method is richer, since it is less structured and can provide new insight regarding new topics [21]. Depending on the type of interview, the interviewer can approach topics that came up during the interview, ask follow-up questions, ask for clearer answers and ask for justifications to the answers given by the interviewees. Interviews can follow three formats [22]:

- **Unstructured:** Interviewer has a list of topics to be covered in the interview. The interview is usually very informal.
- **Semi-structured:** Interviewer has an interview guide with topics and several questions, but the sequence of questions may vary. The interviewer can ask follow-up questions to get significant replies.
- **Structured:** Interviews in which the questions made and their order are always the same.

In this thesis, we have chosen to conduct semi-structured interviews, which is the type of interviews most often used in qualitative research. In this type of interview it is allowed the exploration of topics and other questions that arise during the interview [22].

In semi-structured interviews, the sequence of questions may vary according to the answers provided by the interviewee and on the flow and the development of the conversation between interviewer and interviewee. This also depends on the experience of the interviewer, to *"establish an appropriate atmosphere through which his/her interviewees would feel more at ease and thus talk freely"* [21] and provide their insight about a topic. Although the order of questions may vary from the several interviews, the use of an interview guide ensures that the interviewer address all the questions in the interview guide in every single interview.

### 3.1.2 Cognitive Mapping

Cognitive Mapping is a qualitative technique that allows researchers to represent the knowledge, opinions, and understanding of an individual regarding a specific topic or issue as a graphical representation [23]. Cognitive Mapping can be used as a method to take notes during an interview and can be used to transcript interviews in order to analyze and understand the data retrieved from an interview [24].

Cognitive Mapping helps researchers to structure, organize and analyze data of a person's understanding of specific issues and we choose to use this technique because it offers a graphical representation that manages qualitative information and can be an alternative to take notes during an interview. The representation also provides the results of what was discussed in an interview.

This technique allows to structure thought through symbolic and graphical representation rather than "linear layout, managing a large amount of qualitative information, and can improve interview capability" [23]. Other positive aspect of using this technique is that the information obtained is clearly communicable [23], through the graphical representation of a person's understanding of specific topics.

A cognitive map "consists of a number of concepts, linking lines and arrows, which show and describe how the different concepts are perceived to be related to each other in terms of propositions about the phenomena" [25]. To draw a cognitive map, some constructs [26] are relevant in order to use this technique and they are:

- **Node or concept:** Key elements or statements related to the issue. A concept can have opposite poles, that is, a concept can be an idea and its opposite pole is the alternative to that idea that was also exposed in an interview. The first pole is denominated as emergent pole and the second pole is the contrasting pole.
- **Links:** Representation of the relation between concepts and that imply that one concept leads to the other concept. There are several types of relations, the ones that will be used in this work are:
  - Positive link: Indicates that the relation presented is between the emergent pole of each concept and also between the contrasting poles of a concept.
  - Negative link: Indicates that the relation presented is between the emergent pole of a concept and the contrasting pole of the outcome concept and also represents the relation between the contrasting pole of a concept with the emergent pole of the outcome concept. Negative links are indicated on the cognitive map by the presence of a "-" sign next to the arrow.
- **Arrow:** Indicates the direction of the arrow linking concepts. It also indicates the outcomes of each concept which in turn are also concepts.

The result of the Cognitive Mapping is an hierarchical graphical representation where the nodes or concepts which have no implication (out-arrows) are referred to as a head, and a node or concept which



has no in-arrows is referred to as a tail [26]. Heads are identified as goals that represent the outcomes that a participant identifies based on a specific topic and tails are the starting point for developing a cognitive map.

In order to use the Cognitive Mapping technique it is advisable to follow the following tips [24]:

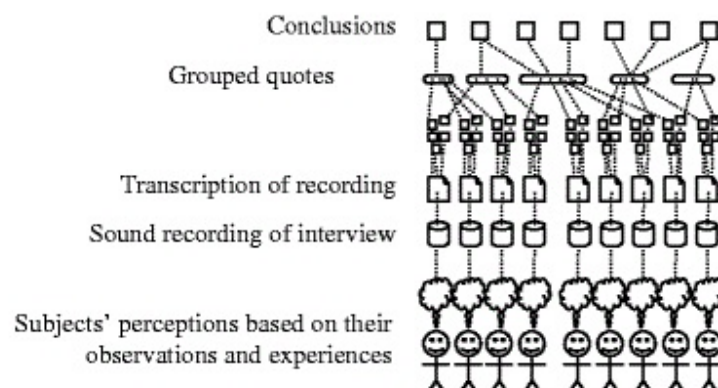
- An account of a problem is broken into its constituent elements, usually distinct phrases of 10-12 words which retain the language of the person providing the account. These are treated as distinct concepts which are then reconnected to represent the account in a graphical format. This reveals the pattern of reasoning about a problem in a way that linear text cannot.
- A pair of phrases may be united in a single concept where the one provides a meaningful contrast to the other, where the contrast allows the user to make and retain a better sense of the other phrase. These phrases are constructs.
- The distinct phrases are linked, each to related others, to form a hierarchy of means and ends. This involves deciding on the status of one concept relative to another.

## 4. Results and Analysis

This Chapter presents the results obtained through the data collected from the two techniques used in this thesis of the applied research methodology and corresponds to the Prepare, Collect and Analyze steps of the CSRM.

In a qualitative data analysis, the main objective is to derive conclusions from the data and keeping a clear chain of evidence [2], therefore the exposure of the data and opinions of the interviewees is key in this aspect. Since the information in the transcripts was textual and the amount of interviews was significant we decided to use a tool to help us in the coding process, that is assign sections of text or testimonials in categories, that are derived by the emerging themes of the interviews [27]. The emergent themes are also known as codes [2] and one code is usually assigned to many pieces of text, and one piece of text can be assigned more than one code. Codes can also form a hierarchy of codes and sub-codes. This process, illustrated in Figure 4.1, allows the grouping of quotes and discovery of patterns in order to expose a chain of evidence. The tool used in this process was NVivo 12 qualitative data analysis software.

Other technique that can be used for qualitative analysis is tabulation, where the coded data is arranged in tables, in order to get an overview of the data. In this document, we will present only tables for the emerging themes, issues, and topics addressed during the interviews.



**Figure 4.1:** Coding process (adapted from [2])

## 4.1 Interviews

The interview guidelines used were based on previous works related to the experience and practice of Scrum in several contexts [9] [28]. We asked several questions regarding the previous knowledge of Scrum before the development of the master's thesis, what were the elements of Scrum present during the development of the master's thesis, how these elements were applied together, if Scrum was really applied, and in their opinion what were the benefits and drawbacks of Scrum in the context of their thesis development. Also we questioned if there were any noticeable improvements and if the use of Scrum was recognized as a factor contributing to the successful conclusion of the thesis.

The interviews were made through Skype, or personally (commonly known as face-to-face interviews) taking into account the preference of the interviewee. Before the interviews, we asked the interviewees for permission to make an audio recording. During the interview, notes were also taken and afterwards a transcript of the interview was created and analyzed with the NVivo 12 qualitative data analysis software. The interview guide used is presented in Appendix A.

In order to perceive how Scrum can help in guiding and manage students during the development of their master's theses, our target audience were students who are, or have been, oriented with the Scrum framework. Fifty-five students were interviewed from different academic years, as can be seen in Table 4.1. Of these fifty-five interviews, twenty-one were face-to-face interviews and the remaining interviews were conducted through Skype. The interviews with the students from the several academic years took place at different times. Students from the 2016/2017 academic year were interviewed in July 2017 and students from the 2017/2018 academic year were interviewed between October 2017 and November 2017. The remaining interviewees were interviewed between February 2018 and May 2018.

**Table 4.1:** Number of students interviewed by academic year

Academic Year	Number of Interviewed Students oriented with Scrum	Number of Students oriented with Scrum
2009/2010	4	8
2010/2011	5	9
2011/2012	5	10
2012/2013	5	11
2013/2014	6	11
2014/2015	6	12
2015/2016	2	10
2016/2017	10	11
2017/2018	12	12

The emerging themes derived from the transcripts were closely related to the questions present in the interview guide and come from the data itself. In the following points we will discuss some of the codes retrieved from the data analysis and present some testimonies given by the interviewees, since "case

study research is richly descriptive, because it is grounded in deep and varied sources of information. It employs quotes of key participants, prose composed from interviews, and other literary techniques to create mental images that bring to life the complexity of the many variables inherent in the phenomenon being studied” [17].

#### 4.1.1 Previous Knowledge

We started by asking the interviewees if they already knew Scrum before they started their master’s thesis and if they had already used or adopted it in some context.

Of all the interviewees, only seven did not know, nor had used Scrum, until they began to be managed with it, during the development of their master’s thesis. Of the remaining forty-eight interviewees, only three said that they did not learn, nor did they used Scrum in an academic context, instead they obtained knowledge about Scrum and used it in professional contexts. One interviewee noted that he used and learned about Scrum in both academic and professional contexts, since he learned about Scrum in a course and then consolidated that knowledge and applied it in a professional internship. The other students throughout their academic career learned about Scrum and developed a project in the context of a software development course. Students also noted that in another course, knowledge was transmitted on theoretical aspects regarding Scrum artifacts, meetings and roles.

Testimony: *“My first interaction with Scrum was on a software engineering course, where we frequently defined sprints and tasks. We had several sprints and in each sprint there was several tasks associated. Each task had an associated state that could be completed, if the task has not started yet or if it is still incomplete, and this helped us to plan the following sprints better, taking into account what needed to be done, which task had more priority and deciding who was responsible for doing it, thus allowing a better management of the work.”*

In Table 4.2 we present a summary of the data collected regarding the interviewees previous knowledge of Scrum before they started their master’s thesis and in what specific context that knowledge was acquired, if that was the case.

**Table 4.2:** Prior knowledge of Scrum of the interviewees

Academic Year	Interviewee	Previous knowledge of Scrum		
		Academic	None	Professional
2009/2010	1		x	
	2	x		
	3	x		
	4		x	
2010/2011	5	x		
	6	x		
	7	x		

Continued on next page

Academic Year	Interviewee	Previous knowledge of Scrum		
		Academic	None	Professional
	8	x		
	9	x		
2011/2012	10		x	
	11	x		
	12		x	
	13	x		
	14	x		
2012/2013	15	x		
	16	x		
	17	x		
	18			x
	19	x		
2013/2014	20	x		
	21	x		
	22			x
	23		x	
	24	x		
	25	x		
2014/2015	26	x		
	27	x		
	28	x		
	29	x		
	30	x		
	31			x
2015/2016	32	x		
	33		x	
2016/2017	34	x		
	35	x		
	36		x	
	37	x		
	38	x		
	39	x		
	40	x		
	41	x		
	42	x		
	43	x		
2017/2018	44	x		x
	45	x		
	46	x		
	47	x		
	48	x		
	49	x		
	50	x		
	51	x		
	52	x		
	53	x		
	54	x		
	55	x		

### 4.1.2 Expectations

We asked students (interviewed while developing this work) that begin their master's theses in the 2017/2018 academic year if they had some expectations regarding the adoption of Scrum in the context of their master's thesis. Only one student had no expectations regarding the use of Scrum in the context of the master's thesis. The rest of the students saw Scrum as a mechanism to help them to be more organized in their work and expected it to be a tool that would allow a closer monitoring by the supervisor.

Testimonies: *"My expectation was that it was something useful and that would improve my performance at work and would not let me accumulate work."*

*"My expectations were that Scrum would help me organize my time better, know what I had already done, and what I needed to do to get a sense of whether I'm on a good track or not in that Sprint."*

### 4.1.3 Elements of Scrum present in the context of the thesis

In terms of Scrum roles, meetings, and artifacts we asked the interviewees which elements commonly applied in Scrum are being and were used in the context of their thesis.

Forty-three interviewees said that a planning component was part of the management process of their master's theses. The interviewees said that this component corresponds to the Sprint Planning meeting of Scrum. Interviewees also exposed that this component is connected with their backlog, that is defined by them as a list of tasks that they committed to do during a Sprint. Forty-two interviewees stated that during the theses guidance and management process a backlog was updated in the several Sprints. During the planning, interviewees informed about the next steps and tasks that were to be addressed in the context of their thesis, and explained that the definition of tasks was a negotiation between the supervisor and the student, in which both gave suggestions of what should be done next in order to establish the next Sprint. Interviewees also said that planning was based on what was accomplished on the previous Sprint, on the review of that Sprint and on tasks that were in the backlog and had not been assigned to a Sprint.

Testimonies: *"There was a component of planning in which the supervisor always gave you an idea of what we you be doing, such as for example researching about related work, in order to have a perspective of what should I do and what will come next. This helped us to plan the following work and to figure out which tasks should I focus on."*

*"The planning part was defined with the supervisor where we always tried to reach an agreement based on our availability and what was going to be done in the following sprints, what were the tasks we had to deal with immediately, what tasks could wait for the next sprint instead to analyze things that were blocked because we were waiting for interviews or answers from someone, for example."*

Regarding the backlog, interviewees stated that this component corresponded to the Sprint Backlog commonly used on Scrum. Regarding this, interviewees noted that was very positive to have a Sprint Backlog during the development of the thesis because when they had some new idea that could be done in the context of their thesis, they wrote it down in the backlog so they would not forget that idea and to discuss it with the supervisor in the next meeting. Interviewees also said that having a backlog with tasks allocated to do in a sprint allowed a focus on that sprint and avoided forgetting about what was agreed to do in that sprint.

Testimonies: *"Every time we remembered a new thing, a new idea that could be done in the context of the thesis, we immediately write it down in the backlog, kept on Trello. Ideas and tasks were present in the backlog and then these tasks and ideas were attributed to specific sprints when we thought it was a good time to work on them. I think this was quite important in terms of organization."*

*"Initially, all ideas were from the supervisor because me and my colleagues did not know what a thesis was and he put in backlog everything he knows that we must do regarding our topic and generic items that everybody must do, such as reading about the related work. From that point, it depends on whether the student gives more ideas or not. I was always very participative because I wanted to do the thesis quickly and then whenever I had an idea I would put it in backlog and then at the meeting we would see if that made sense, or not with the supervisor. In the first Sprints the ideas came from him, but then when we were already inside the subject, we already had more control over the backlog."*

Regarding the review component, thirty-seven interviewees said that review was present in the method used in the management of the master's theses. The interviewees said that the review is made based on the tasks in the backlog. The interviewees also said that they indicated the tasks that were completed, those that were still performing and those that were still to be done and explain what was accomplished during the Sprint. Then the supervisor asked students questions in order to see if the goals of the tasks defined previously had been met and if students, in fact, did the tasks they committed to do during a Sprint, or if the task needed to be addressed again in the next Sprint, in case the objectives had not been achieved.

Testimony: *"The review was based on the tasks, the ones that were in the state done, doing and to-do in that Sprint Backlog and basically giving feedback on what was done, so the supervisor was not limited to just seeing what was done, he would ask what your definition of done was and I would explain and then he would ask me questions, and it is interesting that in addition to believing in you, he asks you a few questions in order for you to question yourself and for him to see if you can answer his questions to realize if we had indeed fulfilled and perceived what was necessary to achieve tasks. We sometimes decided that it was better to perform the tasks again in order to really understand some issues and topics related to the thesis. So, the review was not just to see the tasks and say okay, in every task he effectively asks if we had realized everything and if everything was clear."*

Regarding the retrospective, only seventeen interviewees said that this component was present and used in the management of their master's thesis. Interviewees noted that during group meetings, they exposed the difficulties that emerged during the development of their work and explain how they overcame these problems, or if they have not overcome them, try to solve it with the help of the supervisor and with the suggestions of the other colleagues. Interviewees also exposed that this was very positive, since this allowed to share knowledge regarding the problems and issues that happen during the development of the thesis, and how they could overcome or avoid that problems, since there was a learning experience from the issues, mistakes and solutions of the other colleagues. Interviewees also noted that other perspective of the retrospective was understanding the reasons why a task was not performed during the sprint it was allocated to be performed.

Testimony: *"What I felt was that at the next meeting we talked about the work we had done and what was already happening in that exact moment, and there was always a lot of feedback from the supervisor and from my colleagues in trying to help, in order to improve my work, or redirect it in the right direction and I, in my case had many moments, even in the part of results that I found... I have the vision that there are theses that in a certain way are limited by the things that you can do and since I was in doubt as to what I can do to enrich my thesis more and this part I can map it with the retrospective because I often ended up talking about what had been my week and my difficulties and what I had done and many times I managed with the help of the supervisor, to redirect my work to improve it and get the results I wanted, so I think that the three ceremonies were quite present. Now this depends a little bit of the people and how you expose your theme and topics."*

Fifty interviewees stated that Sprints were present, while they were working on their master's thesis. Interviewees noted that Sprints were the period of time, in which the tasks discussed and agreed with the supervisor should be performed. At the end of each Sprint, these tasks were reviewed, new ones were planned and the Sprint Backlog was established in order to begin a new Sprint, as has been said previously in this Subsection. Interviewees said that these Sprints normally had a duration of fifteen days, that is, two weeks. Interviewees exposed that having Sprints is a mechanism that promotes contact between students and supervisor, which allows students to have several chances to communicate with the supervisor and present their difficulties and the work status in short periods of time.

Testimony: *"Every two weeks, we had a meeting with the supervisor, in which each student looked at his backlog and at the tasks he had agreed that would work and finish in those 2 weeks, that is the Sprint, and it was done a presentation of what was done, feedback was collected and it was decided what was to be done in the next two weeks and we every two weeks basically defined what would be our backlog for that Sprint."*

In Table 4.3 we present a summary regarding the opinion of interviewees concerning which elements of Scrum were applied during the development of their master's thesis. It is noteworthy to mention that



two interviewees from the 2010/2011 academic year felt that no element, commonly practiced in Scrum, was concretely applied in a regular basis during the time in which they were performing their master's thesis.

**Table 4.3:** Elements of Scrum applied according to interviewees during the development of their master's thesis

		Elements of Scrum present in the context of the thesis				
Academic Year	Interviewee	Backlog	Planning	Retrospective	Review	Sprints
2009/2010	1	x				
	2					
	3				x	x
	4	x	x	x	x	x
2010/2011	5					x
	6					
	7					
	8					x
	9	x				
2011/2012	10	x	x	x	x	x
	11	x	x	x	x	x
	12	x	x	x		x
	13	x			x	x
	14			x	x	x
2012/2013	15		x		x	x
	16	x	x	x	x	x
	17	x	x		x	x
	18	x	x		x	x
	19	x	x		x	x
2013/2014	20	x	x	x	x	x
	21	x	x		x	x
	22	x	x		x	x
	23	x	x		x	x
	24	x	x		x	x
	25	x	x	x	x	x
2014/2015	26	x	x		x	x
	27	x	x	x	x	x
	28	x				x
	29	x	x		x	x
	30	x	x		x	x
	31	x	x		x	x
2015/2016	32	x	x	x	x	x
	33	x	x		x	x
2016/2017	34	x	x		x	x
	35		x			x
	36					x
	37		x		x	x
	38		x			x
	39		x			x
	40	x	x			x
	41	x	x		x	x

Continued on next page

		Elements of Scrum present in the context of the thesis				
Academic Year	Interviewee	Backlog	Planning	Retrospective	Review	Sprints
	42	x	x			x
	43	x	x		x	x
2017/2018	44	x	x	x		x
	45	x	x	x	x	x
	46	x	x		x	x
	47	x	x		x	x
	48	x	x			x
	49	x	x	x	x	x
	50	x	x	x	x	x
	51	x	x		x	x
	52	x	x	x	x	x
	53	x	x	x	x	x
	54	x	x	x	x	x
	55	x	x			x

#### 4.1.4 What is the most important element?

After asking the students regarding the ceremonies and artifacts commonly used in Scrum, that were present during the development of their master's thesis, we asked if in their opinion if one of the following elements were more important or were more relevant during the development of this work. Twenty-one interviewees stated that in their point of view, no element stood out in relation to the others.

Nine interviewees exposed that the most relevant element of the Scrum applied during the management process of the master's thesis were the Sprints. These interviewees exposed that Sprints lead to having frequent checkpoints, a focus on specific tasks in a fixed period of time, several opportunities to show the current situation of work, frequent feedback, frequent planning and discussion of tasks, and keep a work pace. Interviewees also noted that due to this work being developed over a very long period of time, many students have the habit of working in the latter stages and do not work in the earlier stages of work, something that does not happen with Sprints, since they lead to the realization of the work incrementally and gradually.

Testimonies: *"The Sprints, I think are the most important because you end up splitting the work into smaller parts, the answer is simple, but maybe the concept of Sprint, that is having many points of situation is the most useful."*

*"We had a backlog, but we did not know all the tasks that we were supposed to do at the beginning. As we were doing Sprints, we were going to think about what the next tasks would be. It was not the waterfall method, we did not list everything that was to be done in the beginning of the thesis, we did it gradually. We were developing small parts of the thesis, the supervisor also advises us to structure*

*the thesis and our thoughts into small scientific articles because these turned out to be small theses within the larger thesis, that is the final work to be delivered. That allowed us to focus on a specific part of the thesis and then it turned to be a part of the final delivery that we made over time and were artifacts produced in Sprints.”*

Eight interviewees said that all the elements present during the development of the master's theses, in their opinion were relevant and that the combination of these elements is very important instead of highlighting a specific component. Interviewees exposed that the components of Scrum are connected to each other and that there is a natural flow and connection between them. Interviews also added that in the meeting with the supervisor, the output of a Scrum component is the input to another part of Scrum to be addressed in that same meeting.

*Testimony: "I think it works as a whole. If you do not have the review, then the planning loses importance, because you will not review the tasks planned to do previously and how you know if the expected goals were achieved. If you do not have the backlog, where you have what you are going to do next, then the planning once again loses importance because you are planning based on the present moment and you do not know very well what have you done before and what you could do after. I think that giving more importance to something is giving less importance to the others and I think they work as a whole and if you only have one Scrum component, it will not have the effects that the conjugation of the various parts of Scrum would have.”*

Seven interviewees said that the most important element of Scrum adopted during the development of their thesis was the backlog. Interviewees noted that having a backlog, allowed to have the defined tasks to be consulted by the student and supervisor at any time and avoided forgetting about what was agreed to do at the last group meeting. Interviewees also said that the backlog was a starting point for the communication between student and supervisor in order to discuss and expose the tasks performed in a Sprint, the problems derived from these tasks and if any of them were not performed.

*Testimony: "In this case, I think if you have a good backlog for each Sprint, even if you do not have a Product Backlog, is very good because you have an idea that is given by the supervisor, or a problem given by him and if you and him can extract from that idea important points to be developed during the Sprint, having this organization in my opinion is the main and the biggest success factor for the development of the thesis, that is having a good backlog organization.”*

Seven interviewees stated that the planning is the most important aspect present during the development of their master's thesis because this was the main focus of the group meeting and that led to the discussion with the supervisor of what were the next steps to be approached and the definition of a set of tasks to be performed in a Sprint.

*Testimony: "I think that if I had to choose the most important concept that makes the students finish the thesis is the planning, that is the way you define with the supervisor, better how it helps you to define*

*the next steps. I think many theses do not end because of the bad planning because you look at the eight months of the thesis and then think the first month is just for the related work, the second month is just for defining the problem and this is a cause that lead to people to not finishing the thesis because if you delay in one part, you delay the whole work, so I would say that planning is the most important for this to be successful."*

In Table 4.4 we present a summary regarding the opinion of interviewees concerning the most important element of Scrum that was applied during the development of their master's thesis. A relevant aspect that deserves to be highlighted is the fact that three students choose two elements, as being the most important, instead of mentioning that in their opinion the conjugation of all the elements is the most important thing because for them these two elements they are more advantageous.

It is important to mention that two students refereed that the most important element was the retrospective, one student said that the most important element was the review, and three students exposed that the most important were the meetings between students and supervisor that we address in the next point.

**Table 4.4:** Most important elements of Scrum applied according to interviewees for the development of a master's thesis

		Most important element of Scrum present in the thesis according Interviewees						
Academic Year	Interviewee	Backlog	Conjugation	Meetings	Planning	Retrospective	Review	Sprints
2009/2010	1							X
	2		X					
	3							
	4							X
2010/2011	5		X					
	6							
	7							
	8							
	9							
2011/2012	10			X				
	11	X						
	12							
	13							
	14							
2012/2013	15		X					
	16							X
	17	X						
	18		X					
	19			X				
2013/2014	20							
	21							X
	22	X						
	23				X			
	24							

Continued on next page

		Most important element of Scrum present in the thesis according Interviewees						
Academic Year	Interviewee	Backlog	Conjugation	Meetings	Planning	Retrospective	Review	Sprints
	25				x			
2014/2015	26							x
	27				x	x		
	28							x
	29							x
	30		x					
	31							
2015/2016	32	x			x			
	33				x			
2016/2017	34							
	35							
	36							
	37							
	38							
	39							
	40			x				
	41							
	42							
	43							
2017/2018	44				x			
	45	x						
	46	x						
	47	x						x
	48							
	49		x					
	50		x					
	51						x	
	52					x		
	53				x			
	54		x					
	55							x

#### 4.1.5 Meetings

After asking what elements of Scrum were present in the interviewees' opinion, we asked if they could explain how these elements were applied together. Forty-four interviewees reported having group meetings, which marked the end and beginning of a Sprint. It was in these meetings that the planning and review that was addressed in the previous point took place. In these meetings, the supervisor brought together all students in the same space.

Testimonies: *"Every two weeks, we had a meeting with the supervisor, face-to-face, in which each student of the thesis looked at his backlog and the tasks that he had agreed that would work and finish in those 2 weeks, and a presentation was made regarding the obtained results. All the students who were being mentored by him met at the same time in a room and in turn, we would be presenting what*

*our work had been and everybody saw what others were doing and other students could contribute with their opinions, even being outside the thesis problem, they could give ideas and suggestions for improvements. It ended up being another source of advices and experiences to improve our thesis, I think this was also more useful for us than if we had an individual meeting with the supervisor, where we only had the feedback of a person."*

*"We have an annual thesis group of master's students from the advisor and every 15 days, these students were all gathered in a room and we did the Sprint meeting in which we started with a student and followed the others in which we explained what I said, what was done in those 15 days, what were the obtained results, what were the conclusions drawn, what had to pass to backlog or to the next Sprint and this was done sequentially throughout the meeting by each student."*

#### **4.1.6 What were the perceived benefits?**

Next we proceeded to ask the interviewees what were the benefits that the adoption of Scrum in the management process of their thesis had brought to them. Twenty-seven interviewees noted that with Scrum and developing the work in Sprints was something that helped to explore the work in the initial moments of the master's thesis in order to address issues that are not well defined. Interviewees noted that at the beginning of the thesis they did not know what the final goal and objectives of their work may be, how they will address it and what has been studied previously in the context of their work. While researching about the work in Sprints, interviewees noted that this allowed to present frequently what was researched in order to perceive the related work and to define the final objective and to refine it in the following sprints together with the supervisor.

*Testimony: "I think in many cases, such as mine, at the beginning of the thesis people rarely know what they will deliver at the end, that is, you have a more or less unknown theme and topic. Only when you research about the theme and the current challenges, the state of the art, only there do you really realize, despite the guidance, what you have to tackle and approach after this initial work of discovery. From this point it makes perfect sense instead of defining the final objective, investigating more areas to understand if they make sense or not, therefore perform the work in an iterative manner is very advantageous."*

Regarding the group meeting, in which the supervisor joined all students together, thirty-nine interviewees said that this meeting was beneficial since it was an opportunity to present and expose to the supervisor the current situation of the work. With this update, thirty-eight interviewees noted that students could obtain feedback in relation to work done in the Sprint and understand if something needed to be improved or needed to be reviewed during the next Sprint, then discuss the next steps and plan the tasks for the next Sprint together with the supervisor. Interviewees also mentioned that Sprints led to having frequent checkpoints, deadlines and deliveries (pointed out by forty-six interviewees) and hav-

ing frequent definition of tasks and objectives (pointed out by forty-four interviewees). These frequent updates also allowed a constant monitoring by the supervisor, an important aspect pointed out by forty students.

Testimony: *"Given the tasks performed for example, since we have these meetings I can provide a summary of what I did and the supervisor give us feedback, for example if he thinks if we have a good work pace. I also explain what problems I had in certain tasks and he explains how I can overcome those problems, or advise me to talk to someone who can help me. In the following Sprints if a similar problem occurs, I can easily reach a solution in that sprint because we have received feedback and that is very helpful."*

A benefit which derives from the feedback, monitoring and the constant updates stated by twenty-nine interviewees is understanding if the work path they are following is correct, that is, with the feedback received and the discussion regarding the next steps and tasks, students have a notion, in their opinion and in the supervisor's opinion, in order to understand if something needs to change regarding the way they perform their tasks.

Testimony: *"Another advantage, with these small cycles is the continuous feedback that you received in order to check your product, which is the thesis. While other colleagues received feedback in later stages of this work, sometimes is very difficult to correct it because the time to do it, is not enough and in our case is gradual. The corrections that we had to make were small, because they were divided over time. With the iterations, the supervisor realizes that our work path may not be right and something different needs to be done in order to redirect us to the right path and without Scrum they would only figure it out this later."*

Twenty-two interviewees noted that the review component and Sprints allowed for an earlier identification of issues. With the frequent exposure of the tasks accomplished and discussion between student and supervisor, this led to students to expose their difficulties and problems that have emerged during the Sprint in order to receive help from the supervisor to unblock these situations. With the group meetings, there was a sharing of knowledge regarding the problems that emerged in the theses of several students and how they overcame these issues alone or with the help of the supervisor. By sharing this knowledge with other colleagues, if a problem previously discussed and exposed by a student occurs in a thesis, the student already has an idea of how to solve that problem. Learn from the work of other colleagues was pointed out as a benefit by thirty-eight interviewees.

Testimony: *"Scrum itself says that we in two weeks do not want to make a final delivery but we want to have something produced to review and change if needed and to not manage things by just having a delivery after three months, after the start of a project, to realize that the things done are not what was expected. Instead of this situation, with Sprints and a bi-weekly accompaniment and monitoring, it*

*prevents the issues and errors from being too large.”*

Since the meeting was held with all students who were being guided by the same supervisor, fourteen interviewees said that this meeting was an opportunity to compare the status and situation of their work with that of the other people present at the meeting. This allowed students to understand whether they were advanced or late in relation to the work carried out in a given moment, in order to understand if they needed to change something regarding the way they performed their tasks. Interviewees also said that these group meetings were a good way to exchange experiences, to listen to the questions of other colleagues and see how other colleagues have solved other problems that may have emerged in their work.

Another benefit exposed by forty-three interviewees was the incremental and iterative nature of the work. The interviewees said that with the bi-weekly frequency of meetings, these were treated as check-points or deadlines. Other benefit related with the incremental and iterative nature of work is the commitment to do the tasks discussed in the planning phase of the group meetings, this made the students more motivated in order to achieve the goals set at the beginning of the Sprint, and helped them develop their sense of responsibility. Thirty-four interviewees stated that this aspect as a benefit of Scrum. Other aspects pointed out by interviewees that derive from these benefits were the accomplishment of tasks and deadlines, the definition of next steps, the division of a large work into smaller parts (pointed out as a benefit by twenty-eight interviewees), establish a work pace (pointed out as a benefit by thirteen interviewees), and learn not to leave work behind in order to meet the final deadline.

Testimony: *“It helps you to transform a big problem, such as a master’s thesis, which has a very long duration. When you start the thesis, you do not know what you have to do and you never had that experience and therefore this method helps here, by starting with small problems that you can solve. It helps you to prioritize things, you know that for 15 days you can do 5 tasks, taking into account the time that you can dedicate to the thesis and the courses and, therefore, compels you to prioritize things very well because you know that at the end of those 15 days you will have to present the work you have committed to do.”*

Another benefit referred by the interviewees related to the group meetings and the Sprint is pressure. Since there was a commitment to do the tasks planned at the beginning of a Sprint and the review and planning were made in a group meeting, there was also a healthy competition in the sense that nobody wanted to fail and had to show the work performed to the supervisor and other colleagues. Three interviewees felt that this component was negative because it did not help to motivate them since they did not appreciate the comparisons made with other colleagues. Other three interviewees stated that in their opinion did not felt pressure as being negative or positive and four interviewees noted that this pressure could be positive or negative depending on the phase and status of work. Thirty-one interviewees stated that this pressure for them was positive, since it was another factor to drive them



to do their tasks in the time agreed with the supervisor and to not leave the work behind. Fourteen interviewees had no opinion on this topic.

Testimony: *"This can be seen as positive and, negative, I see it as positive. This creates pressure and responsibility to whoever is making the thesis to effectively deliver it and for me this is very important and works like the courses, where we know that in the end, we have an exam and if we do not study, we will not pass. In the thesis, there is so much time that sometimes if nobody asks how things are and if there is no pressure, you end up relaxing because you have no pressure to do it and then at the end, when the final deadline is near, you want to do everything in a small time period, but you do not have time and therefore I think that Scrum is key to the continuous monitoring of the work you are doing and any place such as college, such as work, you need to have these checkpoints to effectively evolve and create pressure in yourself because then you end up losing the notion of where should you be."*

In addition, interviewees said that structure (pointed out by fifteen interviews) and organization (pointed out by thirty-one interviews) are extra benefits, which came from the methodology used during the development of the master's thesis. Interviewees stated that Scrum imposed a structure, based on Sprints which made them better prepared to organize and plan in various Sprints that they needed in the context of their thesis development.

Testimony: *"At first, since you have this structure and the subject of the thesis can change, you can start one thing and then the agile part of the method is that you can change requirements and what you want to do. If you had a more strict method you could get to a point where you would have to define everything from the beginning and Scrum allows, given what you have already done explore alternative paths, that is, it gives you the flexibility to change things that are necessary and gives you a structure that is necessary to start a thesis and allows constant monitoring of the supervisor."*

By doing organized work over a length of time, during the stipulated schedule of completion of the thesis and in an incremental way, was considered by students a contributing factor in order to be able to deliver and complete thesis work within the expected time. It was also pointed out by thirty-five interviewees that this method was a good mechanism to conciliate the work on the thesis with the work related to other courses, and this was something important since people tend to pay more attention to tasks near important dates and deadlines, such as assignments and exams, and with this method they were able to focus on both, that is the thesis and each courses tasks.

In Table 4.5 we present a summary regarding the five most referenced benefits of Scrum present during the development and management process of their master's thesis according to the interviewees, which are: having frequent checkpoints, deadlines, and deliveries (referred by forty-six interviewees); frequent definition of tasks and objectives (referred by forty-four interviewees); iterative and incremental development (referred by forty-three interviewees); supervisor monitoring (referred by forty interviewees); exposure of the current situation of work (referred by thirty-nine interviewees).

**Table 4.5:** Five benefits of Scrum that were most referenced by interviewees

		Five benefits of Scrum that were most referenced by interviewees				
Academic Year	Interviewee	Expose the current situation of work	Frequent checkpoints, deadlines, and deliveries	Frequent definition of tasks and objectives	Iterative and incremental development	Supervisor monitoring
2009/2010	1	x		x		x
	2		x		x	
	3			x	x	x
	4	x	x	x		x
2010/2011	5	x	x	x	x	x
	6	x	x	x	x	
	7	x	x	x		
	8	x	x	x	x	x
	9	x		x	x	
2011/2012	10	x	x	x	x	x
	11	x	x	x	x	x
	12		x	x	x	
	13	x		x	x	x
	14	x	x			x
2012/2013	15		x	x		x
	16	x	x	x	x	x
	17	x	x	x		x
	18	x	x	x	x	
	19	x	x	x	x	x
2013/2014	20	x	x	x	x	x
	21	x	x	x	x	x
	22			x		x
	23	x	x	x	x	x
	24	x	x	x	x	x
	25	x	x	x	x	
2014/2015	26	x	x	x	x	x
	27	x	x	x	x	x
	28	x	x		x	x
	29	x	x	x	x	x
	30	x	x	x	x	x
	31		x			
2015/2016	32	x	x	x	x	
	33	x		x	x	x
2016/2017	34		x	x	x	x
	35		x	x	x	x
	36		x	x	x	x
	37		x	x	x	
	38	x			x	x
	39		x			x
	40		x	x		x
	41	x	x	x	x	
	42		x	x	x	x
	43		x	x	x	x

Continued on next page

		Five benefits of Scrum that were most referenced by interviewees				
Academic Year	Interviewee	Expose the current situation of work	Frequent checkpoints, deadlines and deliveries	Frequent definition of tasks, objectives and priorities	Iterative and incremental development	Supervisor monitoring
2017/2018	44	x	x	x	x	x
	45		x	x		
	46	x	x		x	x
	47	x	x	x	x	
	48	x	x		x	x
	49	x	x	x	x	x
	50	x	x		x	x
	51	x	x	x		x
	52	x	x		x	x
	53	x		x	x	
	54	x	x	x	x	x
	55				x	

#### 4.1.7 What were the perceived disadvantages?

After questioning the interviewees about the benefits of using Scrum, we asked the opposite, that is, if in their opinion the adoption of Scrum resulted in some disadvantages. In relation to this subject, the majority of students did not refer and exposed concrete disadvantages they felt during the development of their master's thesis because the perceived benefits were greater than the possible disadvantages and considering that Scrum contributed to the success of their master's thesis. Although few interviewees mentioned some disadvantages resulting from the application of Scrum, we will present and discuss some of them.

Eight interviewees stated that the duration of the group meeting between students and supervisor lasts too long. Interviewees stated that due to the fact that the number of students attending these meetings is high and that each one wants and has the right to expose their work, to try to solve their problems, to discuss the next steps in their work and decide on what will constitute the next Sprint. Interviewees noted that repeating this process between all students it is something very time-consuming, although it is beneficial to observe the developments obtained by the other colleagues.

Testimony: *"These meetings with everyone, I felt a bit unnecessary the time we were there to assist the discussion of other people's theses. In the end I realize why it is important because it encourages you engage with the work in order to reach the colleagues that have the work in a more advanced situation, but it ended up being a burden for me because I also had classes other courses and therefore I wanted to take full advantage of my time and when I was there listen to the other theses. It was beneficial to*

*know in what situation I was in, whether I was late or not, but it turned out to be a long time spent there.”*

Another disadvantage exposed by seven interviewees is the inflexibility of Sprints. Interviewees noted that some tasks are not feasible in a Sprint something that could harm the next Sprints because they have to complete those tasks in those same Sprints. This issue sometimes is only perceived in the middle of the Sprint something caused by bad estimates (a disadvantage pointed out by five interviewees). Interviewees exposed that sometimes the planning of the tasks is not done with the greatest rigor, which can mean that the accomplishment of these same tasks is not possible during a sprint, which could be a consequence of the bad use of the time during the group meeting.

*Testimony: "A disadvantage, but it depends on each of us, but one disadvantage that I consider at first glance is that it forces us to have something done, but in the context of an investigation it is not always possible to do something and having it ready to present it. We navigate here in uncertain seas and typically by forcing every 2 weeks, having some kind of output is not always possible by design because research is not something I will do in 2 weeks. Typically, there is always a time-line to make a thesis, but it is a certain and fixed time-line, but this kind of works do not involve applying a recipe and it is done. No, because there is a lot of subjectivity in the investigation, in the sense, there are work paths that we later see that we are not what we have to follow and then we have to go back and therefore we are faced with these problems and that may not suit with Scrum so well. In an investigation Scrum also makes sense, for the advantages that have already been mentioned, but we also must bear in mind that it can be disadvantageous for those people who like to have freedom and to explore more some subjects and sometimes Scrum forces to restrict the scope and not to explore certain things that would be interesting to see. This could be one of the disadvantages I would say."*

Other aspect pointed out as a disadvantage by three interviewees was the pressure discussed in Section 4.1.6. Other four interviewees noted that this pressure was positive or negative for them depending on the status of their work. In Table 4.6 we present a summary regarding the opinions of interviewees on the pressure that can be generated in the group meetings and the Sprints.

**Table 4.6:** Opinions of interviewees concerning the effect of pressure

Academic Year	Interviewee	Opinions of Interviewees regarding pressure			
		Both	Negative	None	Positive
2009/2010	1			x	
	2				x
	3				x
	4				x
2010/2011	5				x
	6				x
	7				
	8				x
	9				x
Continued on next page					

Academic Year	Interviewee	Opinions of Interviewees regarding pressure			
		Both	Negative	None	Positive
2011/2012	10				x
	11				x
	12				x
	13				
	14				
2012/2013	15			x	
	16				x
	17				x
	18				x
	19				x
2013/2014	20				x
	21				x
	22		x		
	23				x
	24				
2014/2015	25				x
	26				x
	27			x	
	28				x
	29				x
2015/2016	30				x
	31		x		
	32				x
	33				x
	2016/2017	34			
35		x			
36					
37					
38					x
39		x			
40					x
41					
42					
43				x	
2017/2018	44	x			
	45				
	46				x
	47				x
	48				
	49	x			
	50				
	51				x
	52				
	53		x		
	54				x
55					

## 4.2 Cognitive Mapping

In order to have a graphical representation of the principal ideas discussed and exposed by the interviewees, that could aid in the analysis of patterns, we choose to use the Cognitive Mapping technique. From each interview, we have drawn a cognitive map, to make a final cognitive map composed of the most common ideas and concepts presented by interviewees in their interviews.

Since we interviewed several students from different academic years, we decide to make a final cognitive map for each academic year (except for the 2015/2016 academic year, because only two people from this academic year were interviewed, a small number of interviewees compared to the other academic years). The steps taken to draw the maps were as follows:

1. Record the interview and draw a composite map sketch with the interviewees' main ideas;
2. Transcribe the interview and complete the previously done map sketch to obtain the cognitive map of the interviewee;
3. After concluding each map, compare each map, to find common concepts and those that were most exposed by the interviewees;
4. Draw the final map.

In the process of conducting the interviews, we try to draw a sketch, conduct the interview itself, and pay attention to what the interviewee was saying in order to figure out what will be the next question to ask, or if the question itself needed to be further clarified, which made the process of drawing the cognitive map in its entirety somewhat difficult. That's why we decided to take the described steps since it is *"difficult to both listen and understand what is being told him/her whilst trying to remember all the guidelines for creating maps"* [24].

From the maps drawn for each set of interviewees, that is, taking into account the academic year in which they began the master's theses, we can compare and analyze which factors and components students felt were present during the guidance received based on Scrum. The concepts that are part of each map are those that were mentioned and addressed by at least half of the students of an academic year. In this Section, we only present the cognitive map of the 2012/2013 academic year (Figure 4.2) to illustrate as an example of the maps obtained, but the remaining cognitive maps are present in Appendix B and in the following paragraphs we are going to discuss the maps produced under the scope of this thesis and some concepts present on these maps.

Among the several cognitive maps, the concept "retrospective" is only present in two of these maps as a concept (Figures B.3 and B.7), something that is in accordance with what was presented in Section 4.1.3, since the retrospective was the Scrum ceremony that the interviewees least mentioned as being

applied in the thesis management process. The interviewees that referred that the retrospective was present noted that this was a mechanism to realize what went wrong and failed in a Sprint and to understand what can be done better in the next Sprints.

Regarding the final cognitive map of the 2010/2011 academic year, none of the Scrum ceremonies, nor the Sprint or the backlog are represented as nodes, as can be seen in Figure B.2. Despite this, many of the concepts present in this cognitive map reflect attributes that are very common in the practice of agile methodologies such as Scrum. The common agile attributes referred by the interviewees of the 2010/2011 academic year as concepts were: "regular deadlines and checkpoints", "definition of tasks", "earlier identification of issues", "incremental and iterative work", "provide a point of view of the state of the work", and "receiving constant feedback".

In the other cognitive maps, Sprints and the backlog were represented as a concept, thus making these components of Scrum a pattern of the application of Scrum (except for the case of the 2010/2011 academic year, discussed in the previous paragraph).

Regarding the other two Scrum ceremonies, the planning and the review are not present as nodes in one cognitive map respectively, beyond the map of the 2010/2011 academic year. In the cognitive map of the 2009/2010 academic year there is not a node that corresponds to the planning and the review is not represented as a node in the map of the 2016/2017 academic year.

Concerning the interviewees of the 2016/2017 academic year and their cognitive map, presented in Figure B.6, it is important to note that the focus of the group meetings that they had was on the planning, that is in defining the tasks to be accomplished in a Sprint and establish the deadline to perform these tasks. Regarding the interviewees of the 2009/2010 academic year and their cognitive map, that can be seen in Figure B.1, the definition and discussion of tasks to be addressed in the next Sprint was something that derived from the review, since the focus was on discussing with the supervisor what was achieved and what was not, gathering feedback and based on this, decide the next steps and tasks to address (which are placed in backlog).

In the cognitive maps, where the planning is represented as a concept, interviewees noted that this led to deciding the work to be performed, discuss the objectives to be achieved, establish the backlog for that Sprint and having a focus on what to do during a Sprint.

Concerning the review, in the cognitive maps where this was represented as a concept, interviewees noted that this led to exposing the work done in a Sprint, checking with the supervisor if all the combined work between student and supervisor was done and collecting feedback. Other important aspect derived from the review present in only one cognitive map is "earlier identification of issues", which is a concept in the map of the 2011/2012 academic year (Figure B.3).

Although only in this map, the review leads to this aspect, this node is also present in other cognitive maps. For example, in the cognitive maps of the 2009/2010, 2010/2011, and 2013/2014 academic

years, presented in Figures B.1, B.2, and B.4 respectively, "earlier identification of issues or problems" is a node which is derived from "presenting the status of work" (in the case of the 2009/2010 and 2013/2014 academic years), "learning with the work and mistakes of other colleagues" (in the case of the 2009/2010 academic year), "regular deadlines and checkpoints" (in the case of the 2010/2011 academic year) and "supervisor feedback" (in the case of the 2013/2014 academic year).

One very important concept to refer, present in all cognitive maps is the concept "group meeting", that in the case of the map of the 2009/2010 academic year was referred as "regular meetings" by the majority of interviewees of that academic year. This concept is very important because taking into account the information gathered it was in these meetings that planning and review occurred, the backlog was updated, and the meetings themselves marked the beginning and end of the Sprints. These group meetings also lead to the exchange of knowledge, experiences and issues between students, present the status of the work, and positive pressure. These meetings were a key point in the application of Scrum to the interviewees, because as has already been said, it was in these meetings that the concepts of Scrum were applied and adopted.

Other concepts that are present in all cognitive maps are the following: "definition of tasks", "present the status of the work", "pressure", "collecting feedback" and "perform incremental work". The concept "pressure" exposed in the cognitive maps is a positive pressure, in the sense that this pressure was something that motivated students to work and to keep them accountable in relation to their tasks.

In seven maps, the concept "present the status of the work" was a consequence of the group meetings. The only map where this does not verify is the cognitive map of the 2014/2015 academic year, that can be seen in Figure B.5. In this map, this concept is derived from the concept "review".

In maps, in which planning is represented as a concept, it can be verified that one of its consequences is the concept "definition of tasks". In the several maps the designation of this concept can be different, taking into account what was said by the interviewees, but in this case the meaning of this concept is the same for the various maps.

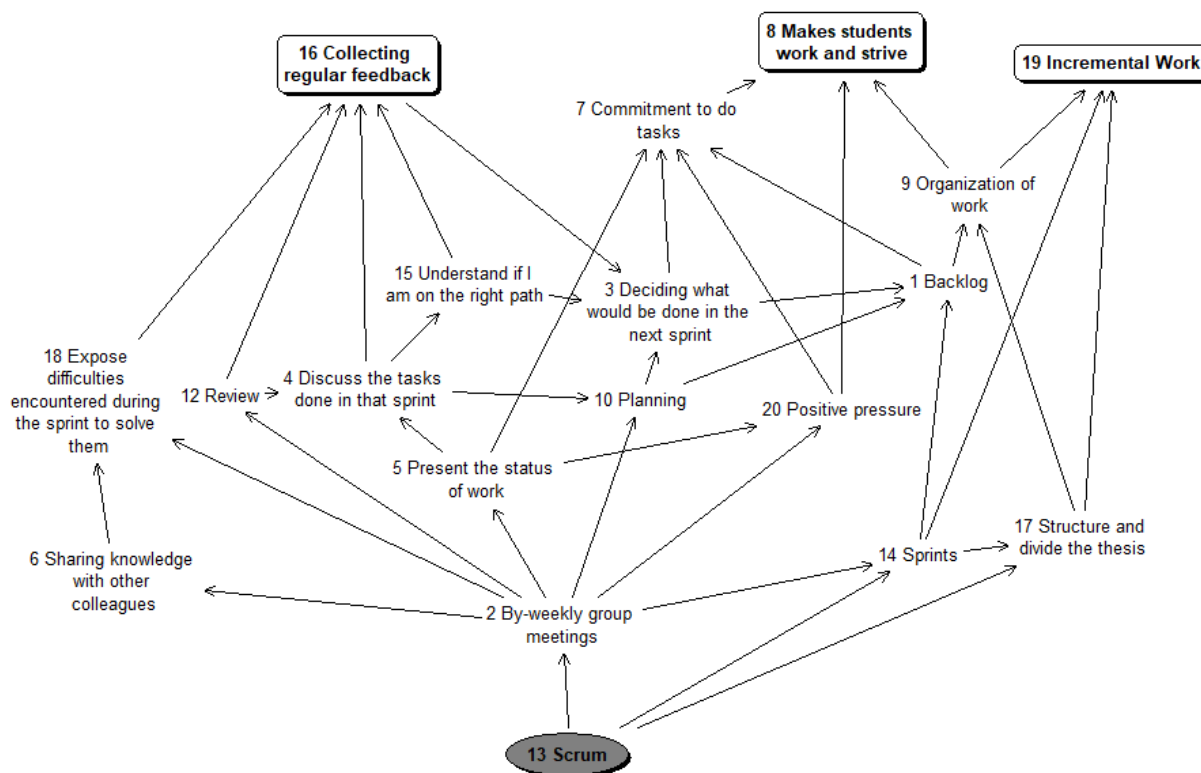
Regarding the concept "incremental work" in many maps, this concept was considered as an head, that is a goal that represent the outcomes that participants identified based on a the application of Scrum during the development of their master's thesis. In our case we considered these head concepts as benefits of the adoption of Scrum. The maps on which this concept is a head are the maps of the 2009/2010, 2011/2012, 2013/2014, 2014/2015 and 2017/2018 academic years. With this concept, interviewees reported that Scrum leads to developing the work in a balanced way throughout the period that the students have to do the master's thesis.

In the maps, the concept "collecting feedback" is closely related with the concepts "understand if I am on the right path" and "review". With the concept "understand if I am on the right path", the interviewees reported that due to regular meetings, frequent communication with the supervisor, and observing the



work of other colleagues, they were able to draw conclusions about the direction of their work, that is, whether they feel they have to change something in the way they approach the tasks, or whether the way they address the tasks leads to the objectives set out and discussed in the meetings.

In Figure 4.2, we can see represented these five concepts that we discussed in the last five paragraphs.



**Figure 4.2:** Final Cognitive Map drawn from interviews with interviewees of the 2012/2013 academic year

In every map the tail, that is the starting point for developing a Cognitive Map and a concept which has no in-arrows, is denominated as Scrum. On two concrete maps, there is more than a tail, as can be seen in Figures B.6 and B.7, the maps of the 2016/2017 and 2017/2018 academic years respectively. In addition to the Scrum concept, the other tails present in the map of the 2017/2018 academic year are the concepts "supervisor availability" (that leads to the concept "group meetings") and "enroll in other courses" (that leads to the concept "conciliate the work from the thesis with the work from another courses", which in turn leads to the concept improve "organization of work"). Concerning the map of the 2016/2017 academic year, the other tails are the concepts "supervisor availability" (that leads to the concept "group meetings") and "amount of work from another courses" (that leads to the concept "task definition and deadlines", together with the concept "Scrum").

Besides the concept "incremental work" there are others that are also an head in the cognitive maps. The other concepts that were represented as an head in the cognitive maps were: "earlier identification

of issues" (in the case of the 2010/2011 and 2013/2014 academic years), "realization of deliverables" (in the case of the 2010/2011 academic year), "make students work and strive" (in the case of the 2012/2013 academic year), "advance work" (in the case of the 2016/2017 academic year), "knowing if I am on the right path" (in the case of the 2016/2017 academic year), "organization of work" (in the case of the 2014/2015 and 2017/2018 academic years), "improve productivity and efficiency" (in the case of the 2016/2017 and 2017/2018 academic years), "improve time management" (in the case of the 2016/2017 and 2017/2018 academic years).

The concept "earlier identification of issues" was perceived as interviewees as the result of the regular deadlines and checkpoints, that is the Sprints, the exposure of the work done in the Sprint, and the discussion about this same work. Interviewees noticed that with Scrum iterations, the mistakes made were detected faster and were corrected in the next Sprint. Other aspect related with this, is the sharing of knowledge, experiences, and issues that occurs in the group meeting, which alerts students to common problems that may occur in their work.

Interviewees from the 2010/2011 academic year also noticed the concept "realization of deliverables" as a benefit, or as a goal of the adoption of Scrum. The interviewees from this academic year noted that by doing their work in an incremental and iterative manner, and since there was a compromise to perform these tasks at the end of each Sprint, these tasks were accomplished. The interviewees also said that if a task was not done on a Sprint, they just had to explain why they did not do it.

Interviewees from the 2016/2017 academic year said that due to the Sprints, they performed their work in an iterative and incremental manner, and by exposing what was achieved at the end of every Sprint that this allowed to have the work in a more advanced status in comparison to other colleagues that did not used Scrum in the management process of their master's thesis.

The concept "make students work and strive" reported as a goal in the cognitive map of the 2012/2013 academic year was derived by the commitment in performing the tasks of a Sprint, the positive pressure, and the organization of work based on Sprints and the backlog.

The concept "knowing if I am on the right path" is a consequence of receiving feedback by the supervisor, given in the group meetings. Since the Sprints had a duration of two weeks, the feedback was received on a regular basis and with this information the students were able to see if they were on the right path to achieve the desired goals for a Sprint, for the work in general, and if it was necessary to redirect their work and the way they approach it to meet the objectives proposed by the supervisor.

Regarding the concept "organization of work", the interviewees from the 2014/2015 and 2017/2018 academic years noted that with the adoption of Scrum and consequently the planning, this lead to establishing Sprints, the tasks to be performed in a Sprint, having those tasks present in a backlog, having deadlines, and divide the workload of the thesis in a distributed manner during the period that students have to finish their master's thesis.

The concept "improve productivity and efficiency" is derived from the motivation of students, the feedback received, the organization of work, realize what went wrong and well in Sprint and understand what can be done better in the following Sprints. These interviewees noticed that these aspects all contribute to understand how to approach their tasks and how to improve the way they do their tasks in order to be more efficient and productive.

Concerning the concept "improve time management", interviewees from the 2016/2017 and 2017/2018 academic years stated that by defining the work that is to be performed in a sprint in a meeting is very useful because they know exactly what they should do and what remains to be done at every moment, because they have the information about what has been completed or not in the backlog. According to these interviewees, these factors lead to the improvement of the time management, given that in each sprint there was a previous planning which allowed the students to perform their tasks.

#### 4.2.1 Domain Analysis

According to Eden an analysis that indicates the richness of the meaning of each particular concept is the domain analysis [26]. This kind of analysis examines each concept and *"calculates the total number of in-arrows and out-arrows from each node, that is its immediate domain"* [26]. This number is also known as cognitive centrality and is defined as the total number of relationships that a concept has with other concepts in the cognitive map [29]. Through domain analysis, it is possible to identify what concepts are the best-elaborated ones or have a higher density of relationships (links) around them. The domain analysis was performed with the Decision Explorer software package.

In Table 4.7 it is presented the five concepts with the most links obtained through domain analysis. In Table 4.7 there are cases where we present more than five concepts for a cognitive map, this is due to the fact that there are concepts with the same number of links and in this case we do not want to omit any of these concepts.

**Table 4.7:** Domain analysis of the concepts of the several cognitive maps

Academic Year	Concept	Links around
2009/2010	13 Regular meetings	9
	11 Backlog	6
	8 Constant monitoring and help from the supervisor	5
	12 Sprints	5
	14 Present the status of work and what was developed in that sprint	5
	18 Discuss what was done and what was not	5
2010/2011	4 Group meetings	10
	11 Regular deadlines and checkpoints	6
	9 Definition of tasks	5
	8 Promotes the delivery of work to be done within the scope of the thesis	5
Continued on next page		

Academic Year	Concept	Links around
	6 Receiving constant feedback	4
	7 Compromise in performing tasks	4
2011/2012	2 Group meetings	11
	6 Perform work in an iterative manner	6
	19 Planning	6
	9 Review	5
	14 Commitment on the part of the students	5
2012/2013	2 By-weekly group meetings	8
	1 Backlog	5
	3 Deciding what would be done in the next sprint	5
	4 Discuss the tasks done in that sprint	5
	7 Commitment to do tasks	5
	14 Sprints	5
	16 Collecting regular feedback	5
2013/2014	2 By-weekly group meetings	7
	15 Supervisor feedback	6
	7 Defining what we would do in the next sprint	6
	6 Planning	5
	12 Review	5
	20 Having a focus on work and have a restricted scope to develop	5
2014/2015	2 By-weekly group meetings	7
	5 Defining tasks to be accomplished in a sprint	5
	19 Having frequent iterations	5
	3 Check if tasks were accomplished	5
	14 Maintain a work pace	5
2016/2017	2 Group Meeting ... Individual Meeting	7
	12 Two week sprints	7
	4 Planning	6
	11 Makes you work	6
	1 Scrum	5
2017/2018	2 Group Meetings ... Individual Meetings	10
	4 Feedback	5
	9 Planning	5
	11 Know if I am on the right path	4
	20 Knowing what remains to be done	4
	24 Division of tasks	4

## 4.2.2 Central Analysis

Central analysis was used to determine how central a concept is in the cognitive map. This kind of analysis is used to calculate a score to determine how central a concept is in the model, that is gives an indication of the influence of a concept in the wider context of the model.

Central analysis is, in a way, complementary to domain analysis. Central analysis looks beyond the immediate environment (links) around a concept and examines the complexity of links at a number of

levels away from the center. *"Picture the ripples spreading out from a central point around a pebble dropped into a pond. The pebble is the central concept and the ripples are the levels at which concepts are given a weighted value. The combined weighting leads to an overall centrality score. The higher the score the more influence the concept has within the model as a whole. A high scoring concept has a complex network of concepts supporting it, and/or a complex network of concepts stemming from it. The highest scoring central concept may not be at the top of the domain analysis results, likewise for lower scoring concepts. This is why central analysis is complementary to the domain analysis"* [30].

This central analysis was also performed with the Decision Explorer software package. The two analysis routines (domain and central) give an indication of the importance of the several concepts in each cognitive map.

In Table 4.8, we present the five most central concepts of each cognitive map.

**Table 4.8:** Five most central concepts of each cognitive map

Academic Year	Concept	Scores Calculated in Descending Order
2009/2010	13 Regular meetings	13 from 20 concepts.
	14 Present the status of work and what was developed in that sprint	12 from 20 concepts.
	23 Review	11 from 20 concepts.
	18 Discuss what was done and what was not	11 from 20 concepts.
	12 Sprints	11 from 20 concepts.
2010/2011	4 Group meetings	13 from 17 concepts.
	11 Regular deadlines and checkpoints	11 from 17 concepts.
	9 Definition of tasks	10 from 17 concepts.
	7 Compromise in performing tasks	10 from 17 concepts.
	8 Promotes the delivery of work to be done within the scope of the thesis	10 from 17 concepts.
2011/2012	2 Group meetings	16 from 22 concepts.
	19 Planning	13 from 22 concepts.
	9 Review	12 from 22 concepts.
	6 Perform work in an iterative manner	12 from 22 concepts.
	14 Commitment on the part of the students	12 from 22 concepts.
2012/2013	2 By-weekly group meetings	12 from 18 concepts.
	1 Backlog	11 from 18 concepts.
	20 Positive pressure	10 from 18 concepts.
	14 Sprints	10 from 18 concepts.
	10 Planning	10 from 18 concepts.
2013/2014	2 By-weekly group meetings	13 from 20 concepts.
	15 Supervisor feedback	11 from 19 concepts.
	12 Review	11 from 20 concepts.
	8 Discuss objectives	11 from 20 concepts.
	7 Defining what we would do in the next sprint	11 from 20 concepts.
2014/2015	2 By-weekly group meetings	13 from 21 concepts.
	19 Having frequent iterations	11 from 21 concepts.
	5 Defining tasks to be accomplished in a sprint	11 from 21 concepts.

Continued on next page

Academic Year	Concept	Scores Calculated in Descending Order
	14 Maintain a work pace	11 from 20 concepts.
	12 Collecting feedback	11 from 19 concepts.
2016/2017	12 Two week sprints	12 from 20 concepts.
	11 Makes you work	12 from 21 concepts.
	4 Planning	12 from 21 concepts.
	2 Group Meeting ... Individual Meeting	12 from 21 concepts.
	1 Scrum	12 from 21 concepts.
2017/2018	2 Group Meetings ... Individual Meetings	16 from 26 concepts.
	9 Planning	14 from 26 concepts.
	4 Feedback	12 from 22 concepts.
	12 Compare the status of my project with other colleagues' work	11 from 22 concepts.
	15 Bring pressure	10 from 23 concepts.

To summarize, the concepts present in all cognitive maps are "Scrum" (tail), "group meeting", "pressure", "feedback", "incremental work" (head), "definition of tasks", and "provide a point of view of the state of work". The concepts present in all cognitive maps are the patterns extracted from the application of this technique. In addition to these concepts, we all also consider as patterns the following concepts: "planning", "review", "Sprints", "backlog", "organization of work", and "understand if I am on the right track". We consider these concepts as patterns because these are present in all cognitive maps, except for one or two of these maps.

Regarding the concepts with more links obtained through domain analysis, the concept "meetings" has the highest value of cognitive centrality in every cognitive map. Other concepts that have one of the five highest values of cognitive centrality and that were retrieved as one of five concepts with greater value in four or more cognitive maps through this routine were "Sprints", "definition of tasks", "feedback", "compromise in performing tasks", and "planning". The only one of these concepts that we still do not consider as a pattern is "compromise in performing tasks".

Regarding the five most central concepts, those retrieved through central analysis belonging to four or more cognitive maps were "meetings", "Sprints", "definition of tasks", and "planning". In the case of concept "meetings", this is one of the five most central concepts in every cognitive maps. This concept and the other three concepts were also retrieved through domain analysis.

## 5. Discussion of Results

The qualitative analysis of the interviewees' opinions and experiences concerning the adoption of Scrum in the management process used during the development of their master's thesis, allowed us to understand which agile practices and benefits of Scrum are present in the method applied to manage students in their work in order to perceive patterns within the data gathered. In this Chapter, we are going to map the results obtained with the results of other studies presented in Chapter 2, that present advantages, benefits, practices and the relationship between the use of agile and the success of projects.

Among the obtained results reported by Mariz, França and Silva, the practices that presented a higher correlation to the success of a project were the regular delivery of software and correct integration testing [13]. Practices such as following agile-oriented project management, delivering most important features first, members with high competence and good relationship with the customer also presented a positive level of correlation.

Regarding the results presented in [13], we can map that the practice of regular deliveries has a positive correlation to the success of a project and therefore of the thesis development process. With frequent meetings (performed every two weeks) and the commitment to do the tasks discussed in the planning phase of the group meeting, there are frequent deliveries and deadlines, as exposed by interviewees, that lead them to following an agile-oriented project management, perform their tasks incrementally, stay focused on work, not wait for the final moment before the deadline to work on the thesis, and according to an agile paradigm this is a relevant factor for the successful development of projects.

Concerning the practice correct integration testing, the interviewees did not specifically mention the practice in the interviews. Interviewees only mentioned the fact that the work they were developing was in an incremental and iterative manner, that is, the work was done from what had been done previously in order to obtain new increments, or parts of the work.

In the work developed by Solinski and Petersen it is presented the significant benefits that originate from the adoption of agile and which practices are commonly used by practitioners of the agile methodologies. According to them, the most significant benefits of adopting agile presented in are knowledge, learning, feedback, and confidence [15]. Regarding our results, we can map these benefits to the feedback that a student obtains during the review phase and the opportunity, in the group meetings to exchange experiences, attend the planning and review process of other colleagues, and understand how other colleagues solve their issues.

Regarding the practices, it is accepted that *"agile with few rigid development practices and balanced processes allow to achieve a higher number of benefits"* [15]. The practices presented in both approaches are: iteration planning meeting, iteration review and retrospective, face-to-face communication, small self-organizing cross-functional teams, frequent planning/reporting, and prioritized list of requirements.

Concerning the practice of small self-organizing teams, the context of a thesis is individual and as stated by the interviewees the key elements are the students and the supervisor, but the responsibility of performing the work belongs to the student and therefore we cannot map this practice with our results since this is an individual work.

Regarding the prioritized list of requirements, we also do not map this practice to our results, since interviewees only exposed that all they have is the backlog of tasks that they are supposed to do in a Sprint, or that have not yet been allocated to a Sprint. Interviewees only stated that tasks were planned to do in a Sprint and that there was a compromise to do these tasks. Interviewees did not refer if these tasks must be accomplished in any order, or if priorities were discussed during the planning phase. This practice is also referred by Mariz, França and Silva as deliver most important features first [13].

Practices such as iteration planning meeting, iteration review, frequent planning/reporting and face-to-face communication are present in the theses management process according to the interviewees. The Scrum ceremonies, in this case, planning and review, take place in the same meeting, where all students are gathered. In the review phase, it is presented the work done and what was accomplished in that Sprint, and then the supervisor asks students questions about the work performed in order to both parts understand if the goals set for the sprint were achieved and understand what should be improved or completed in the next sprint. Moreover, the review focus on the tasks already present on the backlog. Based on this, the student and the supervisor suggest the next steps and tasks in order to select the tasks that the student will do in the next Sprint and commit to. Since this process happens every two weeks, there is a frequent planning/reporting between both parties. The planning and review phase occurs in a group meeting therefore there is a face-to-face communication between student and supervisor. According to Solinski and Petersen these benefits are internal benefits, this is benefits that are related to the agile process used [15]. It is also added by these authors that the most significant external benefit (benefits that refer to the outcomes relevant to a client) is the relationship with the customer [15].

In our case the parties involved are the students who are doing the master's thesis and their supervisor. Although the parties involved are different in our case and in the research developed by Solinski and Petersen it is important to mention that the interviewees felt that the relation with the supervisor is an important factor for the success of the master's thesis, because with the adoption of Scrum and Sprints, this led to having frequent meeting with the supervisor, receiving constant feedback from the su-



pervisor, checking the work done in a Sprint with the supervisor, deciding and discuss the next tasks to be addressed, understand if the work developed was what the supervisor expected. Despite our context being different from the one that was addressed in the research of Solinski and Petersen, this interaction was important for the interviewees because it meant that the tasks were gradually done and discussed every two weeks, something that contributes to the success of the thesis and that it is delivered within the period expected by the students.

According to Rover et al. Sprints and meetings between students, mentors, and clients foster communication. The benefits originating from these practices are teamwork, product quality, customer focus and iterative development [10]. Benefits such as teamwork were not referred by students since the context of the work studied was from an individual perspective. Product quality was also not referred by students as a benefit of the adoption of Scrum in the context of the development of the master's thesis. Regarding customer focus, it is said that each Sprint involves face-to-face communication, feedback, and collaboration with the customer [10]. In this context, there is no communication with a customer, but instead, there is communication between the students and the supervisor at the end of each Sprint, involving face-to-face communication and feedback in order to plan and review the work, topics that we already discussed in this Chapter.

Regarding iterative development, this aspect was already exposed in this Chapter as regular deliveries, since this leads to this benefit. According to Rover et al., *"bi-weekly meetings kept students accountable and motivated them to spread work throughout the semester"* [10], which is also noted by the interviewees as a factor to deliver the master's thesis within the stipulated time.

Begel and Nagappan highlight the top benefits of agile to form a ranking of common benefits. The top three benefits perceived by participants were improved communication, quick releases and quick response of changes (flexibility of design) [16]. Regarding these benefits, the only that we have not yet approached in this Chapter is flexibility of design, and we did not present it as a benefit of adopting Scrum in the management of master's theses development because it was only exposed as a positive aspect by eight interviewees and therefore we cannot map this with the practices and benefits obtained with the interviews.

Mahnic and Rozanc present the results of a survey made in an academic context and in an industrial context to compare the Scrum practices that students perceived as more important for the success of projects based on Scrum with the opinions of professionals in order to understand similarities and differences between the point of view of both parties.

The results presented in [11] show similarities between students and developers regarding the practices that lead to the success of a project. Both parties agree that the two most important success factors are teamwork and communication among team members, and good communication with the Product Owner. These factors were not mentioned by the interviewees, since more than half of them re-

fer that Scrum roles do not make sense in master's thesis development and because this context of this process is individual, but as also stated by the interviewees there is a constant communication exchange with the supervisor, an aspect already addressed in this Chapter.

In [11] it is stressed the importance of the Product Owner for the success of a project, due to his/her vision of what is to be developed, to provide feedback, and answer the questions of the development team, activities that the interviewees said that the supervisor did in the group meetings.

Other practices that were rated similarly were the concept "*done*", Sprint Review meetings, Sprint Retrospective Meetings, and release planning. Regarding Sprint Review, in [11] it is exposed that these meetings are very important to review the work completed and to discuss the next steps for the following Sprint, something that was also stated by our interviewees. The students rated the Sprint Review meeting as the most important Scrum meeting, but professional developers rated the Sprint Planning meeting as the most important of the Scrum meetings. In [11] it is stated that the planning phase is something that contributes to the definition and maintenance of the Sprint Backlog and it contributes to a smooth running of a Sprint. The aspect of the preparation of the backlog was also stressed out by the interviewees during the interviews, in the context of the development of a master's thesis.

The concept "*done*" was rated very high by the students in the research of Mahnic and Rozanc. In [11] it is referred that this practice is related with the acceptance of completed stories presented to the Product Owner in order to understand if what was achieved is what was intended by him/her. The interviewees said that in the review phase, there is a discussion so that the student and the supervisor could perceive in their point of view whether the tasks were completed or needed to be addressed in the next sprint in order to reach the desired goals, but they did not refer if there was a discussion regarding a definition of done for each task, so therefore we can not map this practice with the adoption of Scrum presented previously in Chapter 4.

In summary the practices that have a contribution to the success of projects, as shown in the articles presented in Chapter 2 that we can map to the information gathered in the interviews that we have made are Sprint Planning meetings, Sprint Review meetings, maintenance of the Sprint backlog, frequent deliveries, follow an agile-oriented project management, frequent reporting, feedback and knowledge exchange, iterative development, and frequent interaction and communication with the supervisor.

Based on the interviews and comparing the information obtained from these with the information obtained in the literature on advantages, benefits, practices and the relationship between the use of agile and the success of projects, we can say that the adoption of Scrum and agile practices can help in the success of the development of a master's thesis.

Regarding the issues presented by students who were not satisfied with the guidance received, we can say that an adoption of Scrum is a way to foster communication and contact between students and supervisor, since face-to-face communication is key to the development and success of projects, since

it is a way to provide feedback, understand if a student is complying with what is supposed and desired to do, and to monitor the work. By adopting Scrum and consequently adopt the realization of Sprints and frequently schedule meetings that encompass the planning and review of Sprints (two to four weeks according to Sutherland and Schwaber [6]) is a way to establish a compromise between students and supervisor and have always marked a by-weekly (for example) period of time when both parties reunite in order to present what was done and to provide feedback and monitor the work.

Regarding the insufficient knowledge transmission capacity problem, interviewees noted the effect of having a group meeting with all students guided by the same supervisor as an opportunity to follow the work from other people, learn with their work, their mistakes, and their solutions to the problems encountered during the development of the master's thesis. Interviewees noted that this was very positive because if a problem previously reported by a colleague occur in their work, they might already have an idea how to solve that problem and thus the time spent solving that problem could be minimized and used in performing the remaining tasks. Other knowledge transmission aspect reported was the feedback provided by the supervisor, in the sense, that the supervisor could suggest alternatives ways to perform given tasks, review the tasks performed, and give an opinion on what has been achieved and done. Interviewees noted that this feedback was very important in order to understand if they have to improve their tasks, redo their tasks and understand if what was desired by the supervisor was achieved. Scrum as an agile methodology *"makes people feel purposeful, improves knowledge transfer and learning between team members"* [15].

Other issue presented in Chapter 1 is the longer (than stipulated) average time of theses completion. Scrum promotes the development of work in an incremental and iterative manner, the establishment of Sprint, the realization of planning and review meetings, regular deliveries, frequent reporting, and frequent interaction and communication with the supervisor. These practices can be a contribute in order for the students to deliver their master's thesis within the stipulated time, according to our interviewees when defining the tasks for a given Sprint, there was also a commitment to present these tasks in the following Sprint, something that made them strive to achieve everything that had been proposed and as previously reported Scrum can be a strategy in order for projects to be carried out in an iterative manner, that would prevent students to wait for the final moments to work on them [3] [4].

## 6. Conclusion

This master's thesis had the purpose of examining the experiences and use of Scrum by a group of students that were guided in the development of their master's thesis based on this framework. Within this case study, based on qualitative data gathered through interviews, we presented which practices of Scrum and agile were applied according to the interviewees, and which benefits were generated by them.

Furthermore, in order to understand factors that could lead to the success of this specific group of students, we discussed the work done by other researchers, assessing which practices, and benefits were related to the success of projects that applied Scrum and agile practices in order to compare and map with the information obtained through interviews and the exposure of cognitive maps, resulting from these same interviews.

Based on the information gathered based on students' opinion and the documented effects of Scrum, presented in previous works exposed in this thesis, we explore the issues reported, that occur in students' projects, more concretely in master's theses, and how Scrum can be a strategy to minimize these issues based on its practices and the benefits reported by the interviewees.

With this research work we contribute to the literature with a case study that explores a specific academic context, the adoption of Scrum in the development and management of master's theses, something that has not yet been addressed.

### 6.1 Communication

This Section represents the last step of the CSRSM presented in Chapter 3. In this Section we describe how we communicated and shared our research.

This document itself is part of the communication of our research, we are going to present, discuss and debate it with a qualified jury that is going to evaluate our work. This document will later be public for consultation. Under the scope of this research, we produced two papers with the goal of exposing the obtained results to the scientific community to contribute to the literature with papers describing this case study that explored something that has not yet been addressed, the adoption of Scrum in the development and management of a master's thesis. One of these two papers was accepted, and the other has been submitted, and is still pending acceptance. The list of papers is presented in Table 6.1.

**Table 6.1:** Papers accepted and submitted under the scope of this thesis

Conference/ Journal	Paper	Rank	Status
The 19th Annual Conference on Information Technology Education (SIGITE '18)	Using Scrum for Managing Master Theses: A Case Study	C	Accepted
European Journal of Engineering Education (EJEE)	Supervision of Master Theses Based on Scrum: A Case Study	Q1	Submitted

## 6.2 Limitations

The first limitation we can point is related to the sample of our interviewees. Our sample consisted of students who are, or have been, oriented with the Scrum methodology, since their experience and their understanding was key to draw conclusions about the use of Scrum in this specific context. By interviewing students who did not follow the Scrum methodology during the development of their thesis, we may have obtained information regarding the problems that occurred during the development of their thesis and whether Scrum could have helped in their opinion by exposing them to the practices and benefits perceived by our interviewees.

Other limitation is in relation to the number of interviewees of the 2015/2016 academic year. As we only interviewed two students from that academic year, draw a cognitive map to represent this cognitive year based on only two interviews did not seemed very relevant to us. it would be interesting to have a sample with a similar number of interviewees from another academic years, because certain aspects that could be relevant were not identified and discussed in the analysis of the cognitive maps.

## 6.3 Future Work

For future work several things can be done regarding this research. An interesting one would be performing the same research, but based on quantitative methods, such as surveys for examples, and then perform a quantitative data analysis with the data gathered. Quantitative data analysis is generally performed through statistical techniques, the use of mathematical models, and by explaining and testing hypotheses. In quantitative methods it is commonly asked close-ended questions, that allow to collect quantifiable answers, which in this case could aim to quantify the use and presence of Scrum practices during the development of the master's thesis and quantify the perceived benefits and effects of the adoption of Scrum present in the literature and addressed in this master's thesis.

A research similar to ours, based on a quantitative approach is interesting because it would allow to perform data triangulation with our research, based on a qualitative approach. The purpose of triangulation is *"seeking convergence and corroboration of results from different methods studying the same phenomenon"* [31] and it allows researchers to be more confident of their results, it stimulates the development of creative ways of collecting data, it can lead to richer data, and can uncover contradictions [31].

Since Scrum is something directed towards teams and a master's thesis is a work of an individual nature it would be interesting that for a given group of students, their theses to be interconnected and together form a project. The number of people advised to form a development team in Scrum is between three and nine people [6] and according to our interviewees the number of students attending the group meetings address in Section 4.1.5 was more than nine.

In order to scale the adoption of Scrum and agile in this specific context, it could be through the adoption of the Scaled Agile Framework (SAFe)<sup>1</sup>, which adopts practices of several agile methodologies such as Scrum [32].

There are four versions of SAFe considering the development environment and they are: Essential, Portfolio, Large Solution and Full. The simplest version of SAFe is the Essential version, which encompasses the basic structure of this framework, is the foundation of the other versions, and describes the most critical elements needed to realize the majority of this framework's benefits. The Essential SAFe elements are the following: follow lean-agile principles, real agile teams, cadence and synchronization, program increment planning, releasability, system demo, inspect and adapt events, and lean-agile leadership.

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<sup>1</sup>SAFe: <https://www.scaledagileframework.com>

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# A. Interview Guide

Interview guide template used in the interviews.

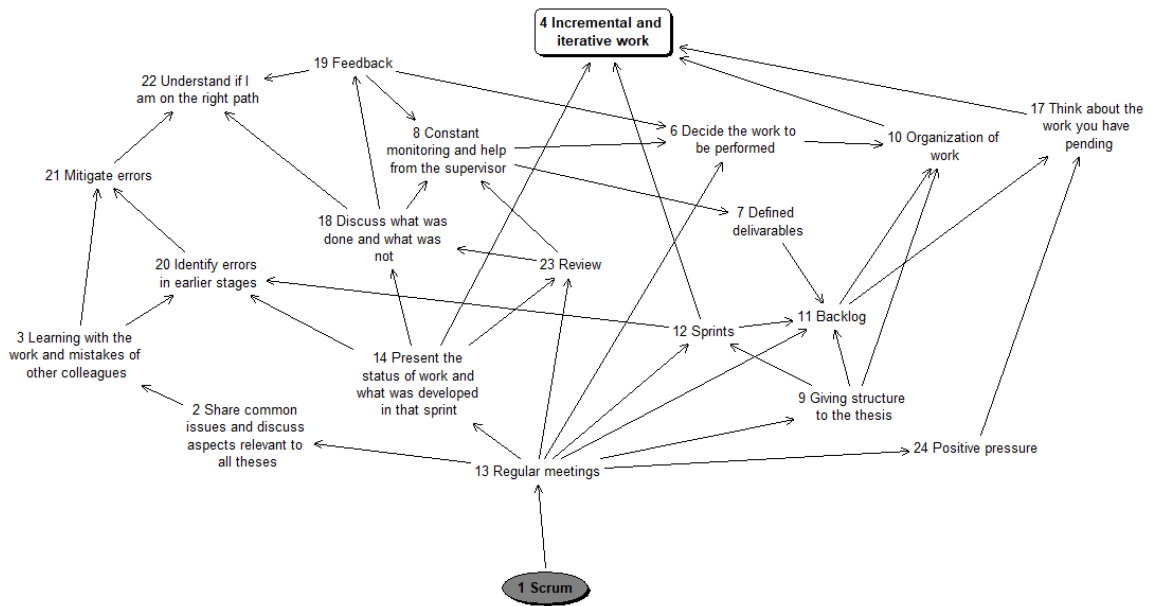
1. Já conhecia a framework Scrum antes de ter iniciado a tese?
  - (a) Se sim, como teve conhecimento sobre a framework?
  - (b) Se sim, já usou a framework em algum âmbito?
  - (c) Se depois da Tese, usou Scrum em algum âmbito?
2. Como é que o Scrum foi aplicado e utilizado durante o desenvolvimento da sua tese de mestrado?
3. Quais os benefícios que acha que o Scrum pode trazer para a realização de uma tese de mestrado?
4. Quais os problemas/inconveniente que podem resultar do uso do Scrum na realização de uma tese?
  - (a) Perguntar no caso específico da pessoa?
5. Em relação aos elementos/artefatos do Scrum (Product Backlog, Sprint Backlog, Sprint, Sprint Planning Meeting, Sprint Review Meeting, Sprint Retrospective Meeting, Product Owner, Scrum Master, Equipa) qual é que acha que teve uma maior preponderância no desenvolvimento de uma tese?
  - (a) Porque?
  - (b) Qual elemento é que acha que vai ter menos importância e porque?
6. Em relação ao uso do Scrum nas teses, para além dos elementos já mencionadas (como sendo o mais importante/preponderante), consegue expor a importância dos outros elementos neste âmbito?
  - (a) Porque?
7. Caso fossem realizadas reuniões (Scrum meetings) durante o desenvolvimento da sua tese, como é que estas eram realizadas? O que era feito nestas reuniões?
8. Durante a realização da sua tese, também fez alguma cadeira?
9. Acha que a utilização do Scrum pode ser algo que ajude a conciliar a realização da tese e as cadeiras que está a fazer?

10. Considera que devido ao uso da framework, se consegue concluir a tese dentro do período estipulado (de forma a concluir a tese com sucesso)?
  - (a) Porque?
11. Acha que devia ser usado Scrum em todas as teses de mestrado?
  - (a) Porque é que deve ser usado?
12. Tem sugestões de melhoria ao método usado durante a realização da sua tese?
  - (a) Se sim, quais?
13. O que acha que deva ser parado de fazer, em relação a este método, que usou durante a realização da sua tese?
14. Quais as competências que um orientador de uma tese tem que ter para orientar os seus alunos com base no Scrum? (Pergunta sugerida)
15. Que outro tipo de abordagens (ou seja, outros métodos para além do Scrum) deve um orientador seguir para potenciar a orientação dos seus alunos tendo em conta a conjugação do Scrum? (Pergunta sugerida)

No final perguntar:

1. Sugestões de perguntas que devessem ser feitas nestas entrevistas?
2. Se algumas perguntas que foram feitas, não fizeram sentido para o contexto em questão?
3. Se deva melhorar algum aspeto na entrevista?

## B. Cognitive Maps



**Figure B.1:** Final Cognitive Map drawn from interviews with interviewees of the 2009/2010 academic year

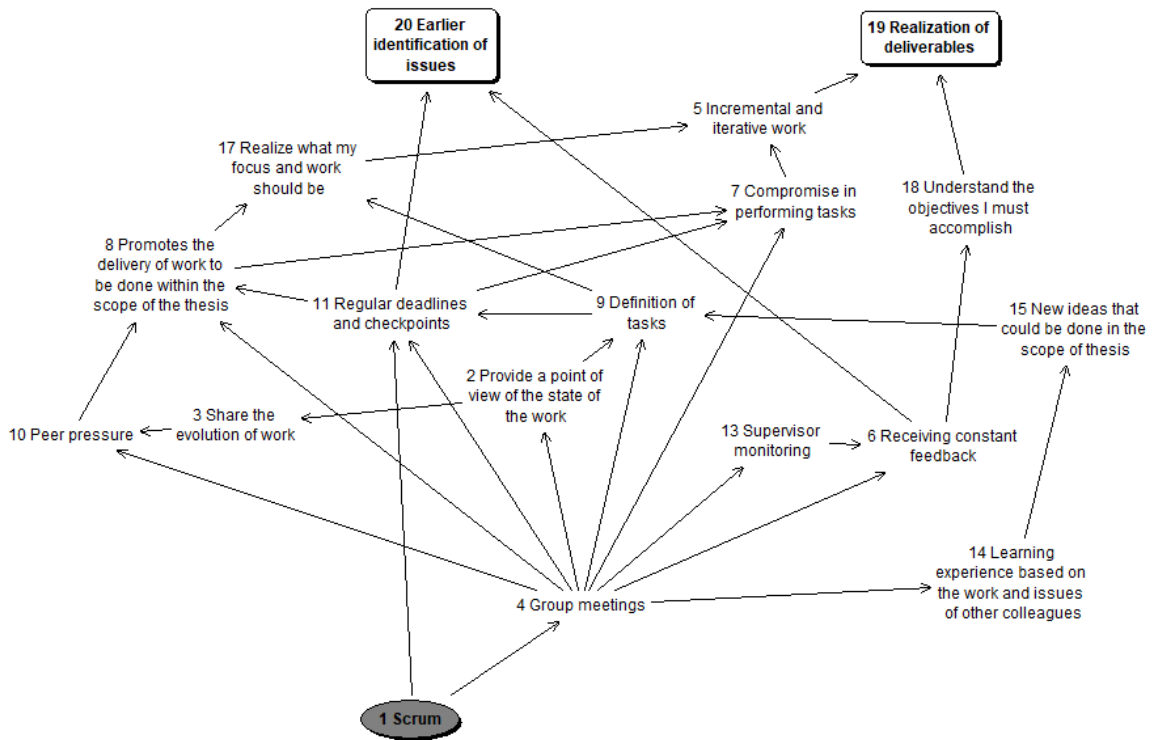


Figure B.2: Final Cognitive Map drawn from interviews with interviewees of the 2010/2011 academic year

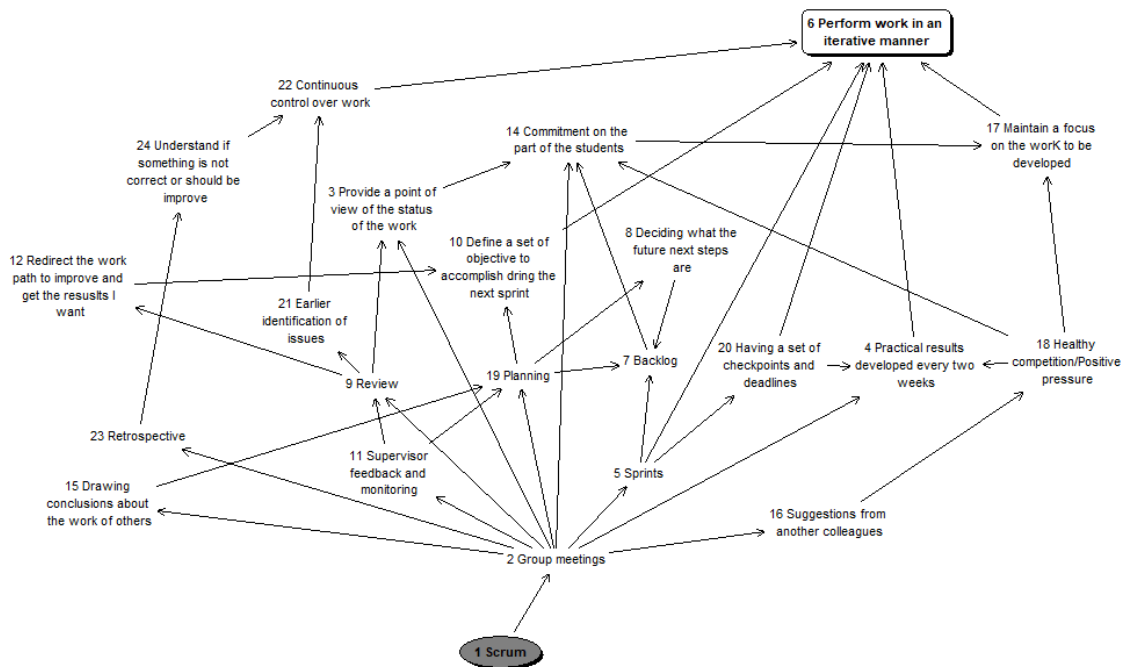
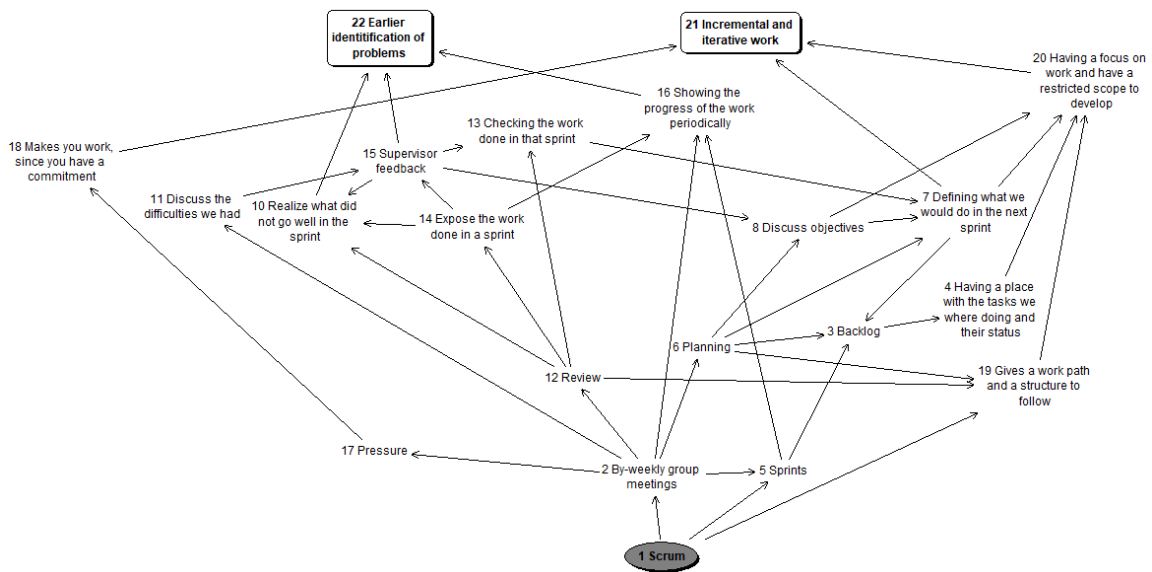
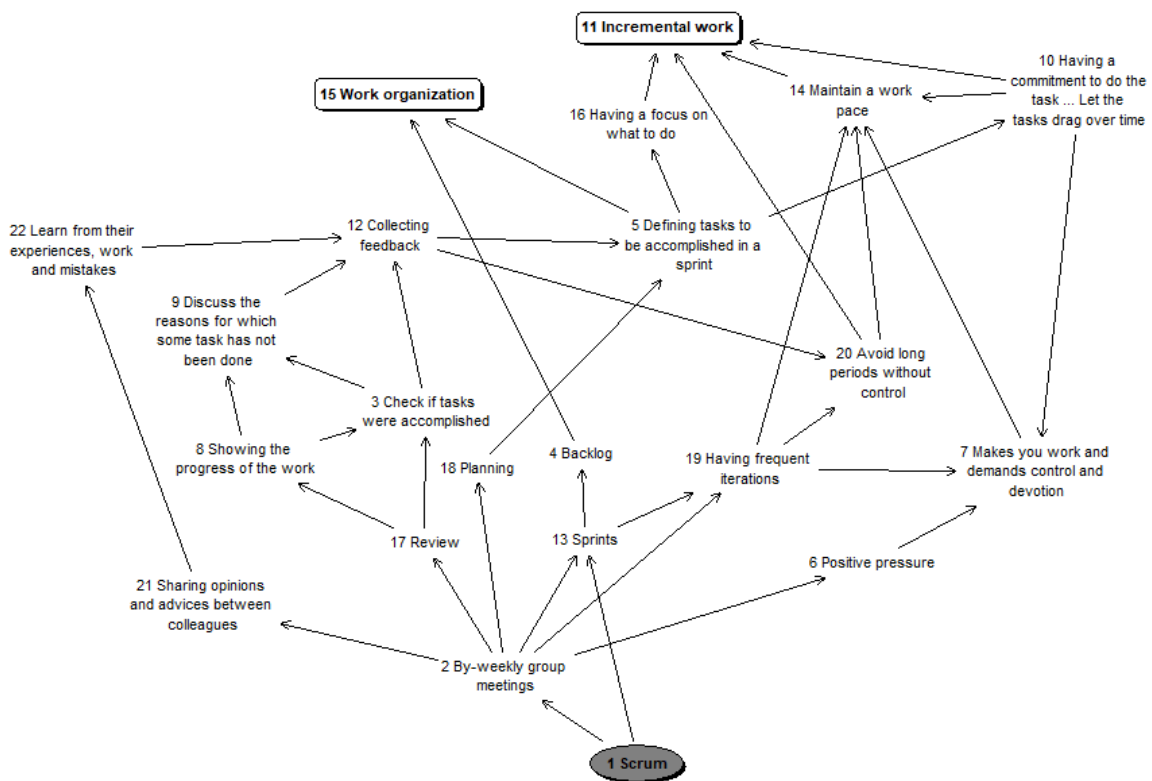


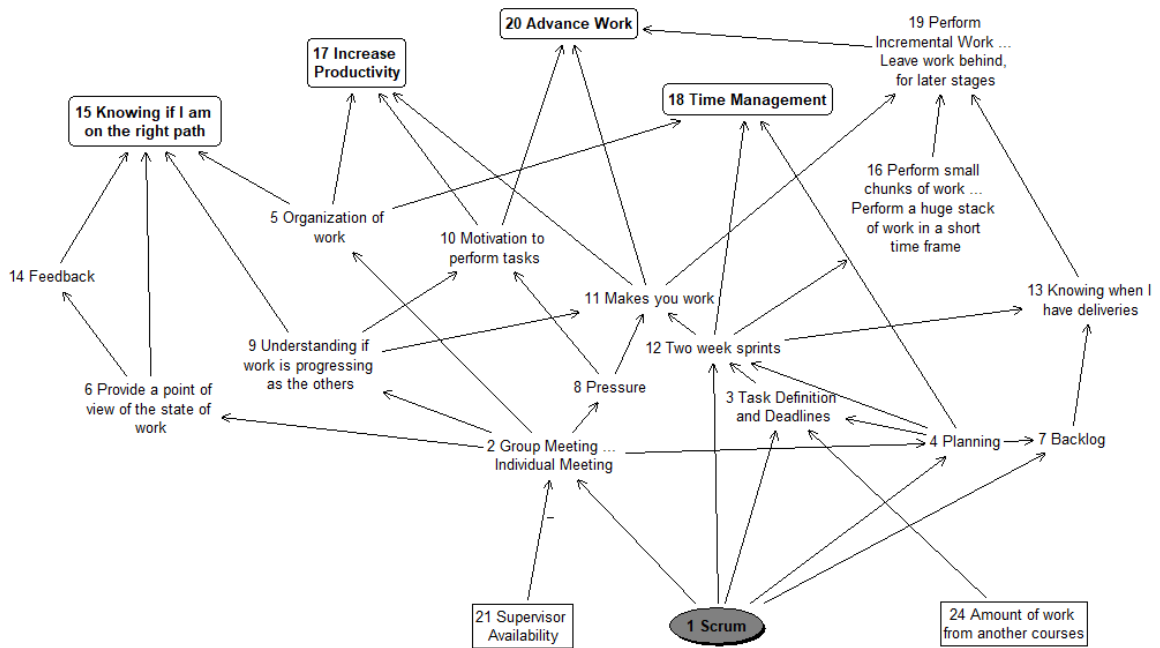
Figure B.3: Final Cognitive Map drawn from interviews with interviewees of the 2011/2012 academic year



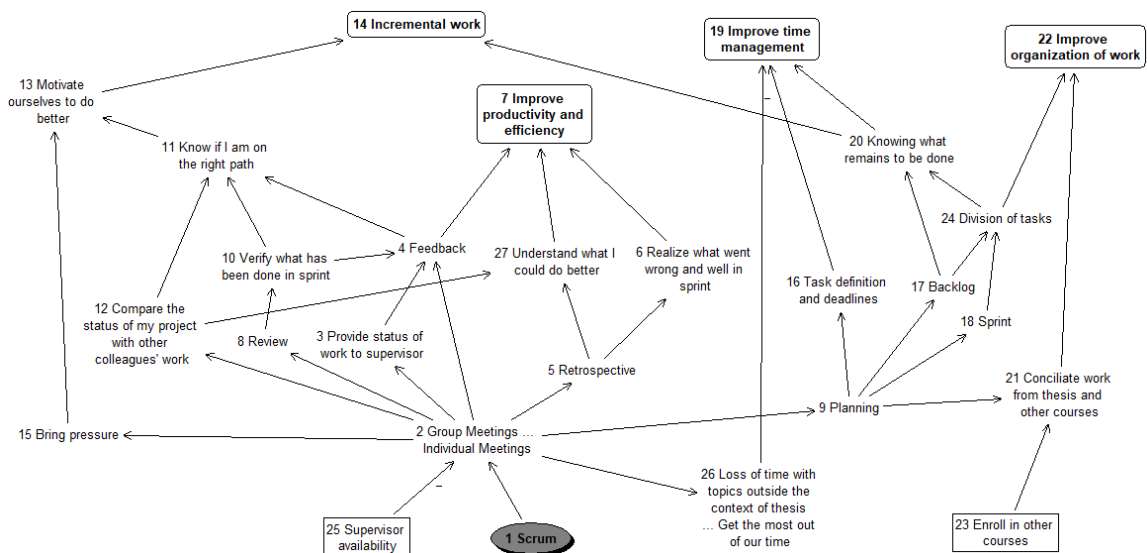
**Figure B.4:** Final Cognitive Map drawn from interviews with interviewees of the 2013/2014 academic year



**Figure B.5:** Final Cognitive Map drawn from interviews with interviewees of the 2014/2015 academic year



**Figure B.6:** Final Cognitive Map drawn from interviews with interviewees of the 2016/2017 academic year



**Figure B.7:** Final Cognitive Map drawn from interviews with interviewees of the 2017/2018 academic year