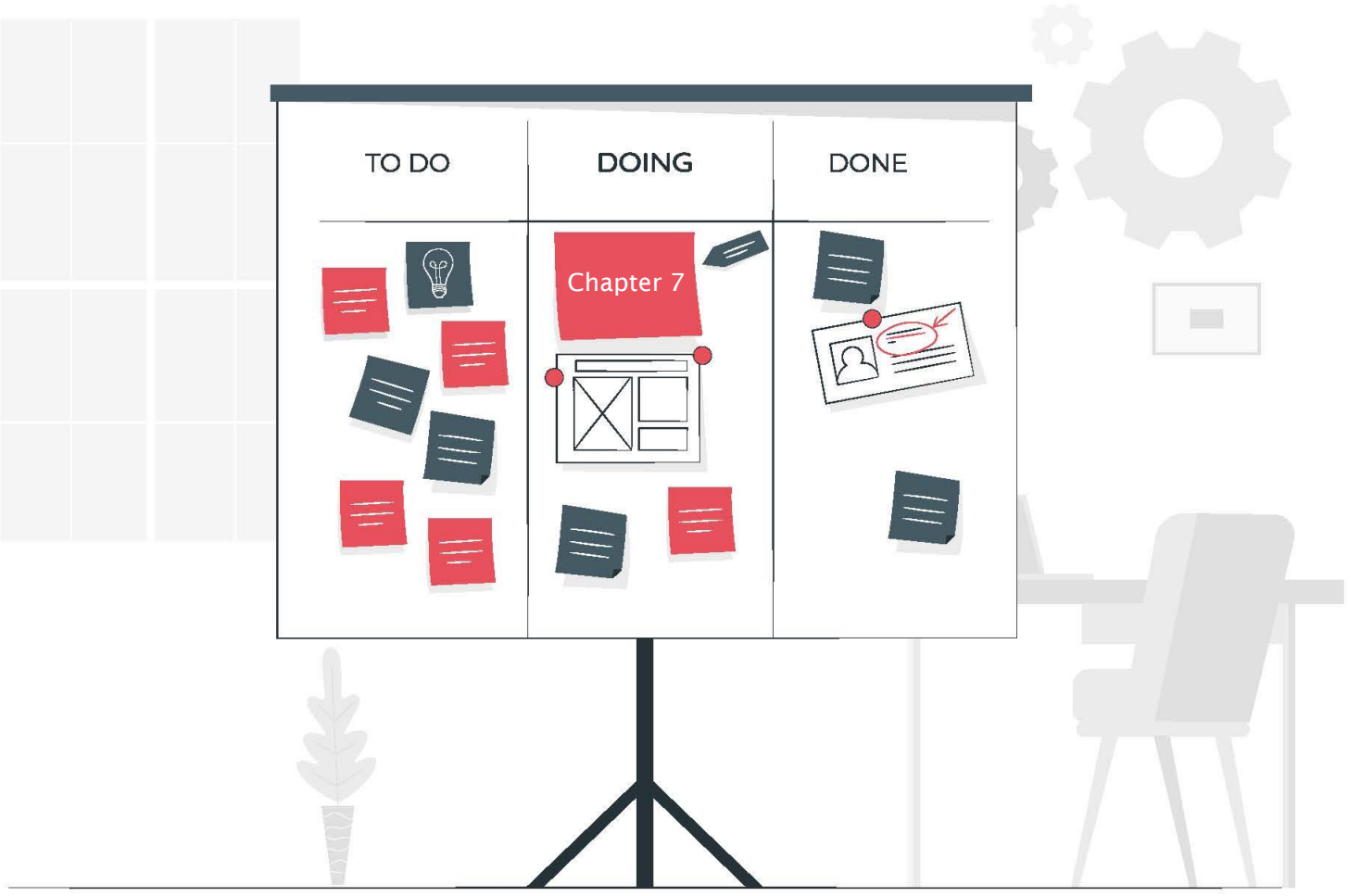
Chapter 7

Summary and General Discussion



7.1 Introduction

This final chapter is about the lessons learned in this thesis. The main research question was: To what extent does Scrum methodology support teachers and scaffold students in their learning in context-based chemistry education? Five studies have been conducted. In the first study, the effects of the use of formative assessments on students' learning achievements were explored in a prospective study (Chapter 2). These formative assessments play an important role within the Scrum methodology approach. In the second study, the potential impact of Scrum methodology on students' motivation was investigated from a theoretical point of view, and, additionally, the initial experiences of three veteran chemistry teachers were collected from semi-structured interviews (Chapter 3). Subsequently, the experiences of chemistry teachers with Scrum methodology were investigated in depth in study 3, with a special focus on the role of teachers' professional identity (Chapter 4). Thereafter, the focus shifted from teachers to students. In study 4, the effects of Scrum methodology on students' (meta)cognitive learning achievements were examined (Chapter 5). Finally, in the fifth study, the impact of Scrum methodology on students' critical reflexive attitude and conceptual understanding were investigated (Chapter 6). All studies were conducted in context-based secondary chemistry education in The Netherlands.

The research presented in this thesis fits within a recent call for studies that focus on potential factors that influence students' learning process in context-based learning environments (Sevian et al., 2018). In a special issue on context-based learning, Sevian et al. (2018, p. 4) emphasized that there is still a need to understand the *underlying mechanisms of learning* as well as *conditions in real classrooms*, that support and scaffold students in their learning process. Below, a summary of the main findings of the five studies will be presented, followed by a description of their contribution to the knowledge base of context-based education and a general discussion. Subsequently, some implications for teacher practice, teacher education and professional development programs will be described. Furthermore, suggestions for future research and limitations will be presented. Finally, from a personal perspective, I will reflect on the question *how* Scrum methodology became a useful framework to strengthen my teaching in a context-based learning environment.

7.2 Summary of the main findings

7.2.1 Study 1

Study 1 offered a typical example of *classroom action research* (CAR) and can be characterised as a prospective study in which the author of this thesis implemented formative assessments in two of his context-based chemistry classrooms. The objective of a formative assessment, or assessment *for* learning, is to provide information on both the learning process and the learning progress. In contrast, a summative assessment can be characterised as assessment *of* learning. Formative assessments are collaborative in nature. Participating students and their teacher receive feedback on students' learning progress and discover misconceptions or knowledge gaps in an early stage of the learning process. Students might use a formative assessment to adjust their learning strategy or to repeat crucial chemistry concepts. Teachers might use the results of a formative assessment to adjust their teaching behaviour to the specific needs of his students.

A pre-test/post-test control group design with switching replications was applied to investigate its effect on students' achievement on their understanding of polymers and asymmetric carbon atoms within the context of lactic acid. Findings revealed that the use of formative assessments had a statistically significant effect. Therefore, this study confirmed educational research which showed, in general, that formative assessments are beneficial for students' achievement (Wiliam et al., 2004).

7.2.2 Study 2

Study 2 focused on the question *how* Scrum methodology might scaffold students' motivation in a context-based learning environment. Therefore, its ceremonies, roles and artefacts were compared with six motivational scaffolds as expressed by Belland et al. (2013). From a theoretical point of view, it became apparent that the Scrum characteristics fit perfectly with these scaffolds, suggesting that the implementation of Scrum methodology is beneficial for students' motivation for several reasons. First, Scrum methodology aims to *promote belonging* (PB). Students participate in teams and work on a shared objective. In addition, students promise to deploy their personal skills to enhance the quality of their common work. Second, artefacts such as a product backlog and scrum board intend to *promote autonomy* (PA). Students plan assignments and monitor their learning progress themselves. Third, ceremonies such as stand-up, sprint and review – which encourage to work on and to achieve short term goals – contribute to *promoting mastering goals* (PMG). Fourth, *expectancy for success* is *promoted* (PES) through the review ceremony, which provides informational

feedback and the retrospective ceremony supporting students to reflect systematically on their learning process. Fifth, the teacher, as product-owner, has an important role to provide students with productive attributional feedback on both conceptual issues and learning strategies. For instance, during a lesson the teacher discusses alternative explanations for negative emotions experienced by a group of students struggling with a challenging learning task, or invites them during the retrospective ceremony to formulate improvements to strengthen their learning process.

In this way, a retrospective supports the teacher to *promote emotion regulation* (PER), which – in turn - contributes to a classroom climate in which short term failure during a sprint and long-term success over the entire course, might add to students' motivation. Sixth, the use of Scrum methodology assumes that students investigate a central question or develop a specific product. Therefore, Scrum methodology might strengthen a context-based learning environment, in which the importance of *task value* is *established* (ETV). Students explore and study a real-world problem, which fosters their interest and which is often closely connected to their personal lives. In addition, study 2 comprised a pilot study in which the initial experiences of three veteran chemistry teachers with Scrum methodology were described. Interview data revealed both enthusiasm and scepticism. All teachers mentioned that starting with Scrum methodology is time-consuming and intense for both students and teacher. However, teacher 1 reported that his students were highly motivated and that they experienced the usefulness of the ceremonies, artefacts and roles of the Scrum methodology. Moreover, he mentioned that the implementation of Scrum extended his teaching style with discussions about students' learning process and learning progress. Teacher 3 emphasized that organizational issues (timetable) as well as a negative classroom climate influenced the implementation. Therefore, she was rather sceptical about the potential benefits of Scrum methodology to improve students' motivation. Teacher 2 appreciated that all the ceremonies, roles and artefacts kept the students on track. In addition, he reported that students' learning achievements were comparable with other years.

In sum: the findings as presented in *study* 2 suggest that Scrum methodology might increase students' motivation and scaffold them in their learning process. Furthermore, the varied experiences of the three veteran chemistry teachers suggest that teachers themselves play a crucial role when Scrum methodology is applied in the classroom.

7.2.3 Study 3

Study 3 focused in particular on the *role of teachers' professional identity* during the implementation of Scrum methodology in secondary chemistry classrooms. Characteristic aspects of teachers' professional identity include: subject matter expertise, didactical expertise and pedagogical expertise (Beijaard et al., 2000). Furthermore, following Beijaard et al. (2000), three additional factors were distinguished: teaching context, teaching experience and personal biography and five other conditions that might influence the entire implementation process: (1) understanding of the concepts connected to the real-world question; (2) alignment of teachers' beliefs with the rationale behind context-based approaches; (3) skills to create a supportive classroom climate; (4) appropriate assessment procedures and (5) the ability to adjust their teaching to the specific needs of students (see study 3). A broad variety of sources, including interviews, a questionnaire, written reflections of participating teachers, and field notes, were used to elucidate the role of teachers during the implementation process. Findings revealed that the implementation of Scrum methodology puts high demands on teachers. Scrum methodology is in itself a rather complex framework, and it takes time to become familiar with all the ceremonies, roles and artefacts. However, interview data showed remarkable differences among teachers. Three out of twelve participating teachers did not report implementation issues, whereas three other teachers mentioned serious organizational issues as well as critical questions of their students and even from students' parents or the school board. These data were triangulated with field notes and the written reflections and suggested two distinct types of teachers, which were characterised as respectively top-teachers and growth-teachers. The other six teachers were less pronounced in how they perceived the implementation process. Given the fact that *there is much to be learned from the particulars* (Helms, 1998, p. 832) the focus was on the differences between top-teachers and growth-teachers.

A clear picture emerged from the data. First, top-teachers had a substantially higher score on didactical expertise compared to the growth-teachers, indicating that they have excellent organizational skills and master a variety of teaching strategies. They planned carefully, had clear learning goals, resources were available and they adjusted their teaching to satisfy the specific needs of their students. Furthermore, top-teachers highlighted the importance of pedagogical expertise, and were able to build positive relationships with their students. Moreover, they created a positive classroom climate. In addition, they asked their students for feedback on a regular basis and provided feedback on both students' learning progress and process systematically. What is notable, both top-teachers and growth-teachers

emphasized the value of solid subject-knowledge expertise, which suggests that this type of expertise is not the distinguishing key factor during the implementation process of Scrum. Differences between top-teachers and growth-teachers with regard to teaching context, teaching experiences and personal biography were less pronounced, suggesting that these factors played a minor role in the entire implementation process. This result was not unexpected, given that all these teachers had taught chemistry for many years, participated voluntarily, and were supported by their school boards to follow a professional development program to implement Scrum methodology.

Therefore, the results of this study underline the importance of both didactical expertise and pedagogical expertise when a teacher introduces additional scaffolds intended to enhance students' learning. Top-teachers created a learning environment which can be characterised with the following key words: positive relationships, shared control, emphasis on learning, ongoing dialogue and feedback, adjustment to specific needs of students. Growth-teachers experienced some resistance among their students. Some students expected the teacher to explain all the chemistry concepts instead of them working collaboratively on a common goal. Other students commented that resources were unavailable and that they did not see the additional value of the Scrum ceremonies, roles and artefacts. Students and growth-teacher had a number of different and sometimes contradictory expectations, which caused uncertainty and dissatisfaction. Despite the challenges, the results showed that all participating teachers appreciated the clear structure of Scrum methodology.

Initially, most participants experienced the framework as rather complex. However, after a certain period, they acknowledged that Scrum contributed to a learning environment in which students' learning process as well as their learning progress become visible. Moreover, they mentioned that misconceptions or uncertainties became apparent in an early stage. In particular, the review ceremony with the formative assessments was experienced as an appropriate tool to get insight in students' learning process. In sum: Scrum methodology offers a framework to enhance and enrich teachers' teaching practice in general and in context-based learning environments in particular. However, effective teaching with Scrum methodology seems to depend mostly on the quality of two aspects of teachers' professional identity: their didactical expertise and their pedagogical expertise.

7.2.4 Study 4

In *study 4* the focus shifted from teachers towards students. More precisely, the study presented in this chapter showed the effect of Scrum methodology on students' cognitive and metacognitive learning achievements. The study was conducted in a context-based learning environment in which students applied the twelve principles of Green Chemistry on two different synthesis routes for adipic acid. It appeared that students participating in the experimental condition outperformed students of the comparison condition with regard to conceptual understanding as well as the quality of a written advice on the greenest synthesis of adipic acid. Furthermore, given that the teacher plays a key role in the implementation process (see study 3) the six participating teachers of the experimental group were divided into top-teachers and growth-teachers. Comparing the learning achievements of students taught by top-teachers with the comparison condition (four teachers) revealed a large effect-size, whereas students of growth-teachers outperformed the comparison condition with a medium effect-size. This is an encouraging result. However, growth-teachers reported some organizational issues and experienced a certain degree of resistance within their classes, nevertheless their students exceeded students of the comparison condition with regard to learning achievements. It suggests that the Scrum ceremonies, roles and artefacts scaffolded their learning. In particular, the review ceremony, in which students used formative assessments to monitor their learning progress and in which teacher and students discovered misconceptions in an early stage might have played an important role to explain the learning gains of students of the experimental condition. In addition, the findings showed that the role of the teacher is not limited to a role in which they facilitate students' learning process. On the contrary, their role is still invaluable.

Findings suggest that top-teachers were actively involved and that they were able to create a *classroom climate* in which students felt comfortable, collaborated, contributed to discussions, reflected on their learning and evolved their skills. Students of top-teachers valued the classroom climate much higher than students taught by growth-teachers and students of the comparison condition.

However, the effects of the use of Scrum methodology on metacognitive and affective dimensions appeared less distinct. For students' *self-regulation* only a small effect-size was found when students taught by top-teachers are compared with the comparison condition. Furthermore, students taught by growth-teachers did not report an increase of their self-regulation. An explanation might be that students of growth-teachers showed some resistance

against the ceremonies of Scrum, culminating in a decreased motivation to self-regulate their learning.

Findings on *self-efficacy* were rather surprising. In general, there is a correlation between learning achievements and perceived *self-efficacy* (Boz et al., 2016). However, students taught by top-teachers showed a small decrease in self-efficacy, which might be explained by the fact that they already had a high level of self-efficacy before they started with the Green Chemistry module. Remarkably, students taught by growth-teachers reported an increase in self-efficacy with a small effect-size compared to the comparison condition, suggesting that they took advantage of the ceremonies, roles and artefacts of Scrum methodology.

Students' *attitude towards chemistry* was affected positively (small effect-size) by Scrum methodology when both experimental conditions were compared with the comparison condition. There is evidence that context-based approaches as well as teacher behaviour are effective in stimulating students to develop a more positive attitude towards science (Lee & Erdogan, 2007).

The finding that students of the experimental condition showed a more positive *attitude towards chemistry* tends to suggest that the Scrum approach is beneficial. Students taught by top-teachers showed an increase of *collaboration* compared to students of the comparison group. Especially the increase of *collaboration* for students taught by top-teachers is worth noting. It suggests that students perceived that they had more opportunities to collaborate with each other. The fact that students taught by growth-teachers and students of the comparison group showed only a small increase on *collaboration*, suggests that the way top-teachers implemented Scrum methodology plays a distinguishing role.

In sum, this study revealed that Scrum methodology is beneficial for students' cognitive learning achievements and to a lesser extent for metacognitive and affective learning achievements when students applied the twelve principles of Green Chemistry on two different synthesis routes for adipic acid.

7.2.5 Study 5

Study 5 focused on a different aspect of the module on Green Chemistry. This module comprised several levels. First, on a conceptual level, students studied the twelve principles of Green Chemistry. Some illustrative contexts were used to explain the chemistry concepts connected to the twelve principles, and, therefore, this part of the module can be characterised as what Roberts (2011) calls *Vision I*. Second, the Green Chemistry principles were applied in

a real-world context on the synthesis of adipic acid. Students were asked to compare and analyse two different synthesis routes. Moreover, they were invited to formulate which synthesis route they preferred. In this way, the students discovered that the principles are embedded in a societal context. Robert (2011) characterises this learning approach as *Vision II*. This vision is seen as an approach to scaffold students to become scientifically literate citizens. In the field of science education, in general, and in secondary chemistry education in particular, there is a clear shift in the educational literature from *Vision I* to *Vision II* (Pilot et al., 2016; Sevian et al., 2018).

Recently, an elaborated form of *Vision II* was proposed, in which students are fostered to reflect *critically* on the context (Sjöström & Eilks, 2018). Moreover, they are invited to reflect on the question how the real-world context relates to their personal lives. This *Vision III* approach is intended to support students to make well-informed, data-based and value-based decisions to become *critically scientific literate*. In this Green Chemistry module, the students were challenged to develop a data-based and value-based decision to choose the greenest synthesis route of adipic acid, in the form of a written advice. A pre-test/post-test control group design was used to explore the effects of the use of Scrum methodology on students' understanding of chemistry concepts and the development of students' critical reflexive scientific literacy. The hypothesis was that the ceremonies, roles and artefacts of Scrum methodology might scaffold the students in their process to deliver a substantiated advice.

Findings revealed that students participating in the experimental condition outperformed students of the comparison condition on several levels. First, statistical analysis of their understanding of the chemistry concepts involved in the Green Chemistry module (*Vision I*) revealed that the scores of the students in the experimental condition were higher than the scores of students in the comparison condition (high effect-size). Second, an analysis of the written advices, in which the students applied the concepts within the Green Chemistry context (*Vision II*) and connected them to their personal lives (*Vision III*) also showed that students of the experimental condition outperformed the students of the comparison condition (medium effect-size).

The analysis was accomplished by using the Standard Observed Learning Outcomes (SOLO) taxonomy, which created the opportunity to classify the written advices to a distinct level. The results showed that the majority of the written advices of the experimental condition reached the *relational level*, which means that data and concepts have been connected and integrated in a coherent whole. In the comparison condition, the majority of the

written advices stayed at the *multi-structural level*, which means that these advices contained several and, in some cases, many isolated concepts, without mutual connections. In both conditions, the *extended abstract level* remained unreached, which means that none of the student groups provided a high-level critical analysis of the real-world question, which is associated with *Vision III*.

In sum, the findings suggest that the implementation of Scrum methodology, in this specific Green Chemistry module, enhanced students' conceptual understanding (*Vision I*). In addition, students using Scrum methodology created higher level advices in which they applied the chemistry concepts involved in the Green Chemistry context (*Vision II*).

Obviously, this might contribute to their scientific literacy. However, implementation of Scrum methodology did not imply that students achieved the intended level of *critical scientific literacy* immediately (*Vision III*).

7.3 General discussion

7.3.1 Contribution of Scrum methodology to research on context-based education

Chapter 1 provided background information on Scrum methodology and a discussion of the three tenets of Scum methodology: (1) transparency, (2) inspection and (3) adaptation (Schwaber & Sutherland, 2017). These tenets will be used to show how Scrum methodology strengthened context-based education.

7.3.1.1 Transparency

Although context-based approaches can be motivating in themselves, some students experience these real-world issues as rather complex and confusing. Their openness might evoke uncertainty about the ultimate objective or the assignments (Parchmann et al., 2006). Teachers participating in study 3 mentioned that the use of Scrum methodology stimulated them to present the learning goals explicitly to their students at the start of the lesson series. Moreover, Scrum forced them to provide their students with a transparent and workable product backlog in which the objectives, tasks and assignments were formulated. In addition, teachers in study 3 mentioned that a scrum board provided insight in students' progress and an instant picture of their individual contribution. In addition, the information on the scrum board displayed delays and, in some cases, collaboration issues. These responses show that the emphasis on transparency might decrease uncertainty among students and strengthen teachers' picture of students' learning process. Although the observation that transparency strengthens a learning environment is not surprising, being transparent in everyday practice in schools is challenging. There are many distractors within schools. Scrum methodology stimulates to be transparent explicitly and continuously.

However, the data of both study 2 and 3 show that creating a transparent learning environment with Scrum methodology sets high demands on teachers. Responses of participating teachers revealed that the implementation of Scrum methodology itself can also be experienced as difficult. In particular, as shown in study 3, growth-teachers reported resistance among their students, indicating that students' motivation was under pressure during their lessons. Students did not see the added value of all the Scrum ceremonies, artefacts and roles. Moreover, these teachers reported organizational issues, had difficulties to provide students with necessary teaching materials such as product backlogs and perceived all ceremonies, roles and artefacts as overwhelming and complex. In contrast, top-teachers were able to create a classroom climate without severe motivational issues or resistance among

their students. They reported that their students collaborated actively and, in addition, that the Scrum ceremonies kept students on track, and scaffolded the learning process. This apparent difference between growth-teachers and top-teachers is an indication that, as with all educational reforms, teachers themselves are crucial. Their didactical expertise, including planning and organizational skills, as well as their pedagogical expertise, which includes how they shape dialogue and feedback, and their adjustment to specific needs of students make a substantial difference.

In sum: context-based learning environments can benefit from the transparency that comes with Scrum methodology although its implementation depends on teachers' didactical and pedagogical expertise.

7.3.1.2 Inspection

In general, context-based approaches are student-centered, which means that students are rather autonomous in how they self-regulate their work. Furthermore, they are supposed to collaborate with classmates, to discuss the distinguishing features of the context and to interiorize the underlying chemistry concepts themselves. Scrum methodology aims to strengthen students to plan and monitor their work in several ways (*inspection*). A stand-up reveals the individual contribution of each team member to the project; the Scrum board visualises what has been done and scheduled tasks and the retrospective aims to provide insight in weaknesses and strength of students' collaboration. Remarkably, only students taught by top-teachers showed an increase in perceived self-regulation as well as collaboration. This is an indication that Scrum can contribute to students' self-regulation and their collaboration in an appropriate classroom climate. It also suggests that Scrum ceremonies can support teachers in facilitating students' learning process.

In addition to these metacognitive aspects of students' learning, the review ceremony is intended to monitor students' conceptual development. The findings of both study 4 and 5 revealed that students participating in the experimental condition outperformed students of the comparison condition with regard to understanding of chemistry concepts. Connecting these results to characteristic statements of teachers in study 2 and 3 suggests that formative assessments, which were used in the review ceremony, might account for the observed effect. First of all, teachers emphasized that the formative assessments were highly appreciated. Secondly, the teachers noticed that formative assessments provide insight in students' conceptual development during the lesson series. Furthermore, formative assessments provided students with an idea of the final level to be achieved and promote mastery of goals.

Knowledge gaps or misconceptions became clear during the learning process, which enabled students to discuss difficult concepts again, or enabled the teacher to adjust his teaching to meet the specific needs of the students. According to the teachers, their students recognized the added value of formative assessments. These findings suggest that the observed effects of Scrum methodology on learning outcomes are likely to be associated with the use of formative assessments. In addition, study 1 of this thesis revealed that students benefit from the implementation of formative assessments. Students using formative assessments outperformed students of the comparison group. This result is completely in line with other studies on the effectiveness of formative assessments (Black & Wiliam, 2009) and is an indication that the review ceremony is crucial in developing students' conceptual understanding. Furthermore, the findings of study 5 seem to suggest that the ceremonies of Scrum methodology can play a role in shaping students' critical reflexive attitude. Students participating in the experimental condition outperformed students of the comparison condition with regard to the advices they wrote. However, caution is required for the interpretation of this result. Both study 3 and study 4 revealed that the role of Scrum is strongly intertwined with the role of the teacher.

In sum, Scrum methodology can induce systematic and explicit inspection of both students' learning process and students' conceptual understanding. Although the implementation of all ceremonies is challenging, this study shows that is worthwhile to use a project management framework to scaffold students' learning in context-based learning environments.

7.3.1.3 Adaptation

The emphasis on transparency and inspection during the lesson series enables teachers to adjust their teaching to the specific needs of students. Adaptation is a key tenet within Scrum methodology and especially this aspect might support teachers and scaffold students within context-based approaches. Study 3 showed that the review stimulates teachers to take note of students' learning progress. Teachers had to develop appropriate formative assessments which forced them to rethink intended learning objectives. Moreover, the results of the formative assessments provided insight in misconceptions in an early stage and encouraged them to adjust their teaching to the specific needs of their students. Study 3 provided some examples of how teachers adjusted their teaching as a result of feedback they received from their students. Teacher Rodney developed formative assessments on two different levels to satisfy the demands of his students. Teacher Paul took uncertainty of his students seriously and

convinced them that he would provide the help necessary to master the chemistry concepts. In addition, data from study 4 revealed that top-teachers were able to create a classroom climate in which students felt comfortable, engaged and willing to provide feedback.

The findings show that a learning environment shaped by Scrum methodology offers opportunities for teachers and students to discuss cognitive and metacognitive aspects of their learning. However, its effectiveness strongly depends on teaching quality.

7.3.1.4 Conclusion

Scrum methodology provides a useful framework which supports teachers and scaffolds students in context-based learning environments by creating transparency, by providing moments of inspection and by offering opportunities to adapt to the specific or even changing circumstances. However, to obtain its benefits it is not enough to solely implement Scrum methodology. It is necessary to focus on teachers' behaviour in general, and their didactical expertise and pedagogical expertise, in particular.

7.3.2 How Scrum methodology supports teachers and scaffolds students in context-based learning environments

As with most educational research, it is impossible to provide a single, straightforward reason to explain the findings. However, the findings of the current study suggest at least two possible explanations. First, Scrum methodology creates a playfield with clear and explicit borders, which evokes systematic monitoring of students' learning and enables them and their teachers to adapt their (teaching) strategies. The second explanation relates to the role of the teacher. These two reasons play a role in six dimensions of students' motivation in education supported with Scrum including establish task value (ETV); promote mastery goals (PMG); promote belonging (PB); promote autonomy (PA); promote emotion regulation (PER) and promote expectancy of success (PES) (Belland et al., 2013). Furthermore, the two main explanations can be connected to the elements of what Boss and Larmer (2018) have called the Gold Standard of project-based learning, including a real-world issue, voice and choice for students, reflection, feedback, revision and communication.

7.3.2.1 Scrum methodology as playfield with clear borders

Scrum methodology can support teachers to emphasize the value of the real-world issue and to share the learning goals, tasks and the ultimate objective. This transparency might decrease uncertainties and promote high expectations for success (PES). Moreover, students are invited to ask for clarification when they perceive the entire assignment as vague (ETV). In addition,

they are invited to plan, monitor and visualise their work themselves. Students' 'voice and choice' are appreciated and encouraged, which can contribute to a learning environment that promotes autonomy (PA). The short, iterative cycles (sprints) might promote mastery of goals (PMG). During the sprints, students communicate about planning and conceptual issues. Especially the review ceremony evokes mutual feedback on the quality of students' understanding. The use of formative assessments seems to be crucial. Educational research has shown the benefits of formative assessments for students' learning (Wiliam et al., 2004). Within the playfield of Scrum methodology these embedded formative assessments receive systematic attention, which enhances students' learning outcomes significantly (study 4 and study 5). At the same time the review ceremony might invite students to re-study concepts they failed to understand or revise intermediate products. The retrospective ceremony aims to strengthen mutual feedback and reflection on both collaboration issues and learning strategies, which might contribute to emotion regulation (PER). Students collaborate in groups in which all team members are valued for the personal qualities they deploy for their team, which might promote feelings of belonging (PB).

Considering these six dimensions, it seems that adding Scrum ceremonies, roles and artefacts to a context-based approach can create a learning environment which directs and visualizes students' learning progress and enhances students' learning achievements. In addition, it appears that Scrum methodology reinforces many elements of the Gold Standard of project-based learning, including: explicit attention for an authentic real-world problem, encouragement of students' voice and choice, systematic moments of reflection and feedback, invitation to revise and improve learning, and promotion of communication (Boss & Larmer, 2018).

7.3.2.2 The role of teachers

The findings revealed that Scrum methodology flourishes when teachers are didactical and pedagogical experts. Teachers facilitated the learning process with their didactical skills by providing and deploying teaching materials (a product backlog, a scrum board, reviews etc), stimulating their students to use the Scrum ceremonies and explaining why these ceremonies have added value (ETV, PES). In addition, they deployed their pedagogical expertise by creating a classroom climate in which students feel comfortable and willing to collaborate (PB). They *shared control*, invited students to develop their own learning path (PA) and had an open mind for students' feedback. They took students seriously concerning their feelings or uncertainties and promoted emotion regulation (PER). In such learning environments

students can discuss conceptual issues, develop their critical reflexive attitude and reflect on metacognitive aspects of their learning (PMG). Obviously, these teacher qualities are not unique for Scrum-based learning environments. On the contrary, it underlines that the role of teachers is invaluable in Scrum just as it is in any educational context.

7.4 Implications for professional development and teaching practice

The findings of this thesis revealed that the role of the teacher in implementing Scrum methodology is crucial. The results in study 3 revealed that the implementation sets high demands on teachers. Therefore, before implementing Scrum methodology, it is strongly recommended for teachers to attend a professional development program in which they study and discuss the rationale behind Scrum methodology, in which they practice the ceremonies, roles and artefacts and share initial experiences. Furthermore, teachers need to become aware that a sound base of subject-knowledge is not enough to implement Scrum methodology. Both knowledge and skilled use of their didactical expertise and pedagogical expertise are essential and need a lot of exercise in the classroom. Several teachers explained underlying reasons during the professional development program. First, they emphasized that the exchange of experiences and the discussions to overcome certain challenges helped them to persist in using Scrum methodology in their classes. Furthermore, they highly appreciated that they shared chemistry as subject, which made it easier to recognize both challenges and opportunities as perceived in the specific circumstances of a context-based chemistry class. In addition, during the implementation process the participants noticed that they needed suitable formative assessments for the review ceremony. However, development of formative assessments is a time-consuming process. After finishing the professional development program, they decided to apply for a grant (Leraren OntwikkelFonds) to develop appropriate teaching materials to be used in their Scrum lessons. As a result, pairs of teachers developed and shared formative assessments on a variety of topics including: acid base chemistry, biochemistry, reaction kinetics and redox chemistry. This unexpected spin-off shows that collaboration between chemistry teachers of different schools can have major advantages.

7.5 Limitations and future research

The research presented in this thesis fits in a recent call to study the conditions in which learning in context-based secondary education occurs and can be enhanced. However, the specific circumstances of a context-based learning environment in secondary chemistry education limits the generalizability of the results. It is recommended for future studies to

implement Scrum methodology in other learning environments and other school subjects to find out to what extent its ceremonies, roles and artefacts impact students' learning achievements and their attitudes. Furthermore, this research was conducted relatively short after the introduction of Scrum methodology in the classrooms. Although the participating teachers followed a professional development program, they were rather unexperienced in the use of Scrum methodology when the research was conducted. In addition, their students were also unfamiliar with the framework. This might have caused uncertainty and even some confusion and resistance among the participants. Therefore, it is recommended to conduct an extended study on the effects of the use of Scrum methodology on cognitive and metacognitive outcomes, such as self-efficacy and self-regulation.

Participating teachers chose voluntarily to implement Scrum methodology in their classes. They were motivated to explore the opportunities of Scrum. Therefore, these teachers might deviate from the 'average' chemistry teacher with regard to their motivation. However, their scores on subject matter expertise, didactical expertise and pedagogical expertise did not deviate from scores of 'average' chemistry teachers, which suggests that participating teachers do not deviate from their colleagues (see study 3). However, although there is a lot to learn from the experiences of just a few teachers, a study with more teachers increases the diversity and opinions of participating teachers, which might strengthen the robustness of the results.

Findings in this thesis with regard to students are based on pre-test/post-test measurements, written advices and self-reported perceptions of metacognitive aspects of their learning. A follow-up observation study might document and analyse actual students' behaviour next to their self-reported perceptions to find out the differences with regard to collaboration, self-regulation, self-efficacy and development of personal qualities in classes with or without Scrum methodology.

7.6 Concluding remarks

The entire set of ceremonies, roles and artefacts of Scrum methodology contributes to a classroom environment in which transparency, inspection and adaptation shape and enhance students' learning process. Teachers play an invaluable role in creating the necessitating transparency, in providing feedback and in adjusting their teaching to the specific needs of their students. The introduction of methodologies developed in the field of businesses in an educational context opens new unexplored frontiers to enhance both teaching and learning.

7.7 Personal reflection

Teaching is fascinating. Teaching is appealing, multifaceted and – to a certain extent – unpredictable. Teaching settings vary from day to day and from hour by hour. However, despite its unpredictability there are tenets that shape and enhance a teaching process. In this paragraph I reflect on my teaching experiences from a personal perspective. Furthermore, I reflect on the question why Scrum methodology fits within my teaching strategies.

Cooking and baking. After my graduation I started to teach chemistry in secondary education. Immediately I experienced the immense differences between a chemistry lab and a classroom. The metaphor of cooking and baking can be helpful to address these differences. Synthesizing a new molecule in a laboratory can be compared with *baking*, whereas teaching can be compared with *cooking*. A baking process requires a precise procedure with well-known parameters. Although the process to find the appropriate parameters can be time-consuming and complicated, a skilled analyst is able to develop a process that can be replicated with the same results. Synthesis of a certain product can be controlled, measured and tested. In contrast, cooking requires continuous tasting and – for instance - adding of extra flavours to create a tasteful diner. Teaching requires a constant adjustment to the specific needs of students and changing circumstances. Outcomes are sometimes unexpected and surprising. Although content and learning goals might be identical for two classes, teachers never reproduce their lessons exactly. I realized that teaching is a complex endeavour and much more than delivering content to thirty youngsters. In successful lessons there was humour, and intense interaction about content as well as more personal subjects. This experience was an important lesson for me, which was phrased by Roosevelt when he said: *"Nobody cares how much you know until they know how much you care"* (Hammon, 2014). During my PhD-project this saying was confirmed when I interviewed colleagues and when I visited classes. A beautiful example can be found in *Chapter 4* in which teacher Paul adjusted his teaching to the specific needs of one of his students: *"Trust me, I know exactly what I am doing. (…). I guarantee that you will master the chemistry concepts. If necessary, I will explain difficult topics to you and your classmates."*

Confusion. Back to the start of my teaching career. Initially, my lessons were rather straightforward , and – to be honest – they must be characterised by *chalk and talk* (Ültay & Çalık, 2012, p. 687). I explained chemistry concepts on the blackboard and expected my students to listen, to take notes and answer – often lower-order thinking – questions. However, there was still room for laughter and fun. Obviously, in terms of *Chapter 4*, my teaching was based predominantly on subject knowledge expertise and pedagogical expertise.

Or, in terms of *Chapter 6*, my teaching style fitted primarily within Vision I, which can be characterised as *teaching to the test* and a clear focus on *transfer of knowledge* from teacher to students. Although my students performed well on their final exams, after some time I noticed some confusing situations. The first situation concerned the experiences of an intelligent and brilliant student. After his graduation he started his study of chemistry at university. However, to my surprise, he quitted several months later. It turned out that he was unable to plan and monitor his learning process. In the same period all teachers of my school followed a professional development program on how to strengthen students' involvement during lessons (*Alle leerlingen bij de les*). Within this program all teachers were invited to shift regulation functions from teacher to students. We discussed and exercised with a variety of teaching strategies to activate students' learning and to stimulate them to take responsibility for their own learning. My role as a teacher shifted to a more facilitating role. However, results on summative assessments were rather disappointing. Students were confused and uncertain about what was expected and were insufficiently provided with tools to check their learning progress throughout the semester. Despite the literature to suggest that an active role for students is beneficial for their learning (Ebbens & Ettekoven, 2000), in practice I experienced the challenge to involve all students in their learning.

Context-based approach. Meanwhile some intriguing developments emerged in the field of secondary education. Active student participation was stimulated by the introduction of context-based approaches. The rationale behind the introduction was that a well-designed context, with a strong connection to students' personal lives, evokes commitment among students. Chemistry concepts are not to be transmitted directly to students. On the contrary, concepts need to be discussed collaboratively and students construct their own coherent mental model. It was exciting to be involved in the development of context-based approaches on antibiotics and lactic acid (see: www.scheikundeinbedrijf.nl). Students were motivated, had the opportunity to plan their work themselves and were challenged to collaborate. However, the Hawthorne-effect could have played a role in this period, because of my own enthusiasm to implement context-based approaches. Moreover, some students remained uncertain about what to learn for the final summative assessment. To overcome this issue, we developed an appendix in which core concepts were explained separately. Initially, students appreciated this part of the context-based approach. However, after some time they asked why it was necessary to study the entire context. According to them it was enough to study the core concepts. Obviously, despite a variety of attempts to activate students, many of these attempts fell short. This period, in which both the context-concept approach as well as a large

educational reform (Tweede Fase) were introduced in secondary education, forced me to think about my didactical expertise. An important question for me was how I could guide my students effectively through their learning process, enhance their self-efficacy, strengthen their self-regulation skills and provide suitable tools to scaffold their learning.

Coaching. My personal opinion included that I had to develop my coaching skills. Moreover, I had to enlarge my teaching toolbox with additional teaching strategies and innovative tools and artefacts. In addition, I needed evidence to substantiate the effectiveness of interventions. A small study on the effects of formative assessments (*Chapter 2*) revealed that its implementation was beneficial for students' learning achievements. My students mentioned that the formative assessments provided a clear picture of what they were expected to know, and as a teacher I discovered in an early stage what they misunderstood, which created new opportunities to discuss difficult concepts. Although the evidence was in part anecdotal, I concluded that the implementation of formative assessments was helpful for students and contributed to their self-efficacy. This simple tool, which was rather easy to develop, helped both my students and myself to monitor their learning progress and provided opportunities to reflect on conceptual issues. Currently, I use formative assessments throughout a lesson series. However, the emphasis of formative assessment shifted from the final assessment to the learning goals. A future development will be that the formative assessments are available within an electronic learning environment, which will enable students to monitor their progress autonomously. Although the implementation of formative assessments contributed to a learning environment in which students' learning process is systematically monitored and which promoted reflection there were still elements to be improved in my lessons, including how to scaffold students in their planning process and how to support them during the learning process.

Conditions. Despite the advantages of formative assessments, coaching and facilitating students on their way to become self-confident and autonomous learners, remained challenging. I noticed planning issues, ineffective use of time as well as issues concerning collaboration among students. I was searching for a teaching approach in which planning, monitoring, support and reflection formed a coherent whole that supported teachers and scaffolded students when they were working in a context-based learning environment. For me, all these conditions met within Scrum methodology. An interesting workshop during a conference stimulated me to follow a professional development program on Scrum methodology. I introduced Scrum in one of my classes and experienced enthusiasm among my students. Furthermore, I discovered that this framework provided ceremonies, roles and

artefacts that: (1) visualized students' planning (Scrum board); (2) systematically monitored students' conceptual development (review with formative assessment); (3) supported me to provide knowledge and teaching materials just-in-time, and (4) created moments of reflection on both collaboration issues and learning approach (retrospective ceremony). Furthermore, students' qualities were taken seriously in the group forming ceremony and students had *voice and choice*. Initially I experienced that the implementation of Scrum methodology caused uncertainty. Scrum is in itself rather complex, which was confirmed in the studies presented in Chapter 3 and 4. However, the results in both Chapter 5 and 6 showed that Scrum methodology enhances learning outcomes, even when teachers experience challenges during the implementation process. Although Scrum methodology sets high demands on teachers, including myself, it helped me to create a classroom climate in which students were rather autonomous, without being directionless. Scrum methodology supported me in finding an equilibrium between a laissez-faire and a rigid, directive learning environment. Scrum supports me in sharing control with my students.

Covid-19. The viral outbreak of Covid-19 in Spring 2020 changed everything. Within 48 hours all lessons were given online. As with the lessons before, I started with learning goals, provided some explanations on core concepts and invited students to discuss assignments or exercises together. I provided formative assessments and asked students to upload their answers in the electronic learning environment. However, it was difficult to adjust my teaching to the specific needs of students, it was hard to find out how they collaborated and it was challenging to organize online interaction with them. Obviously, both pedagogical and didactical aspects of my teaching were under pressure and my teaching style lapsed back to a more directive style. If the current conditions continue, I will try to share control and search for electronic alternatives for a Scrum board, for group forming ceremonies et cetera. Obviously, teaching requires interaction among students and between teacher and students. These moments of interaction provide information to adapt the needs of students. Sometimes students need an explanation or extra teaching materials and sometimes they need emotional support.

Conclusion. Teaching is complex. It comprises more than delivering content. In my view Scrum methodology provides useful ceremonies, roles and artefacts that scaffold students' learning and supports me as a teacher to adjust my teaching to the needs of my students. Teaching requires continuous learning. Teaching remains fascinating.