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A teacher perspective on Scrum methodology in secondary chemistry education

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Scrum methodology is a novel framework for teaching intended to scaffold students' learning process when they work on complex, real-world tasks. It is originally a project management framework frequently used in business and industry to manage projects. Scrum methodology is increasingly used in educational contexts. Yet, it is also a rather complex framework and more insight in how teachers understand and implement Scrum methodology is needed. Twelve teachers attended a professional development program and simultaneously implemented Scrum methodology in their chemistry lessons. Teachers' didactical expertise and pedagogical expertise appeared to play a key role during the implementation process, whereas teachers' subject matter expertise, and other factors such as teaching context, teaching experience and personal biography seemed to be less important. Didactical and pedagogical expertise enhances teaching with Scrum: it supports the implementation as well as increases its effectiveness, independently of teaching context, experience and personal biography. This would mean Scrum methodology offers possibilities for teachers to enhance and enrich their teaching practice.

Introduction

Currently, context-based approaches are widely accepted in secondary science education in general and in secondary chemistry education in particular (Sevian *et al.*, 2018). Gilbert *et al.* (2011) argued that context-based approaches aim at creating a learning environment in which students are involved actively, in which they work collaboratively on a meaningful real-world question and regulate their learning processes (Taconis *et al.*, 2016). Educational research has revealed that these approaches can increase students' motivation and their positive attitude towards chemistry, while learning achievements are comparable or even better than regular approaches (Eilks and Hofstein, 2015; Savelsbergh *et al.*, 2016; Bennett, 2017; Ültay and Çalık, 2012).

However, despite these promising results, the implementation of context-based approaches in chemistry classrooms has not progressed, indicating that implementation is challenging for students and teacher. Parchmann *et al.* (2006, p. 1058) reported that some students experienced *feelings of getting lost* in the complexity of a context and uncertainty about the learning goals. Quintana *et al.* (2004, p. 359) emphasized that students can be overwhelmed by the complexity of options available and often possess insufficient knowledge and metacognitive skills to make relevant decisions in authentic, open-ended learning contexts. But not only students experience problems. King and Ritchie (2012, p. 75) reported that, due to perceived time constraints, a reflective, competent and willing chemistry teacher lapsed back to a more traditional teaching style during the implementation of a context-based unit in her classroom. De Jong (2012, p. 126) emphasized that many teachers show resistance towards educational innovations, caused by a variety of reasons, including feelings of insufficient expertise in guiding students through their learning process and their beliefs about what good education entails. Despite the development and introduction of interesting methods to empower teachers (Bulte *et al.*, 2006; Vos *et al.*, 2011; Sevian *et al.*, 2018), there is still a need for additional tools or frameworks, that strengthen teachers to scaffold students' learning (Mergendoller *et al.*, 2006).

Scrum methodology could be an appropriate framework to support context-based secondary chemistry classrooms. This methodology is intended to scaffold students' learning process when they work on complex, and sometimes overwhelming, projects.

We did not find examples where Scrum methodology was introduced in context-based chemistry courses. However, Scrum methodology has gained ground in education to structure self-regulated learning (Parsons and MacCallum, 2019). It was implemented in several educational contexts, including software engineering (Magana *et al.*, 2018) and professional writing courses (Moses, 2015; Pope-Ruark, 2015). Mahnic (2010) reported that participating students perceived their software engineering

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course as appealing. Moreover, Kamthan (2016) and Cook (2017) advocated for the introduction of Scrum methodology to improve mutual collaboration and reflection among students and teacher. Experiences of students during a project-based learning approach are described by Dinis-Carvalho *et al.* (2018) which showed that students recognized the advantages of Scrum methodology and scored above average compared to students using regular teaching approaches.

Scrum methodology includes ceremonies, roles and artefacts, and should provide structure and overview. Its iterative character invites reflection on both learning process and learning progress and evokes feedback among students and teacher (Pope-Ruark, 2015). Implementing a lean and transparent methodology might decrease the perceived complexity of student-centered learning environments and enhance mutual collaboration. We hypothesize that both teacher and students might benefit from Scrum methodology. However, knowledge of how teachers implement this rather complex methodology is lacking. Therefore, this study aims to provide insights into what teachers require to implement Scrum methodology. This was investigated in context-based chemistry classrooms.

First, a concise overview of Scrum methodology is presented, followed by a description of teachers' changing role when using Scrum.

Overview of Scrum methodology as used in context-based chemistry courses

Scrum methodology was initially developed in the 1990s as a project management framework frequently used in business and industry to manage complex projects, especially in the field of software development (Schwaber and Sutherland, 2017). The term 'scrum' originates from rugby, and refers to rugby players forming a powerful group, positioned in a specific way to conquer the ball. Scrum provides ceremonies, roles and artefacts to monitor progress, to adjust to changing circumstances and to reflect on quality of intermediate products. In an educational context, Scrum methodology might be an answer to collaboration issues often perceived by students (Pope-Ruark, 2012). In an essay on the use of Scrum methodology in education, Vogelzang *et al.* (2019) connected characteristics of teaching with Scrum methodology to several aspects of students' motivation, including their autonomy, expectancy of success, feelings of belonging and regulation of emotion from a theoretical point of view. In addition, Vogelzang *et al.*, 2019 included initial experiences of three teachers, in the form of a small pilot study, that were used to illustrate how Scrum methodology might be implemented in an educational context.

A typical Scrum project in an educational context starts with a teacher, in the role of product-owner, presenting a rather complex, real-world question to his students with an explicit ceremony. The teacher clarifies the learning goals, connects the real-world question to the personal lives of his students and provides students with artefacts such as a scrum board and a product backlog, which comprises a list with exercises and assignments that are necessary to answer the real-world question (Fig. 1).

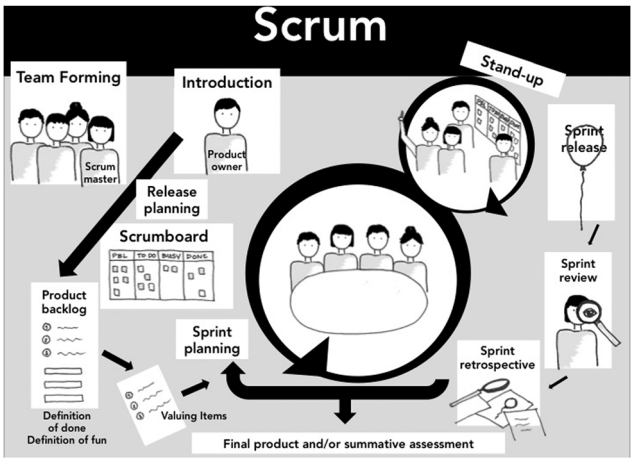

Fig. 1 Overview of Scrum methodology, retrieved from (Vogelzang *et al.*, 2019).

Students work collaboratively in groups of four, in which one student is Scrum master, who takes initiatives and contacts the product owner when problems arise. Each group is supposed to work on the real-world question for a period of approximately six weeks, with two or three lessons a week. Each lesson starts with a stand-up ceremony in which team members discuss their progress, problems perceived and today's learning goals. The ceremony takes place in front of a Scrum board, which basically consists of three columns, named 'to do', 'doing' and 'done'. A Scrum board is an artefact that provides overview for students and teacher at a glance. The column 'to do' consists of all tasks, written on post-its, necessary to answer the main question. 'Doing' consists of the tasks in progress and when a task has been completed it is positioned in the column 'done'. The six-weeks' period is divided into three iterative 'sprints' of two weeks each, reducing the overall complexity of the real-world question. Finishing a sprint is done by releasing an intermediate product or by performing a formative assessment (Andrade and Heritage, 2017). Reviewing and discussing the quality of an intermediate product between product-owner and group are intended to enhance its quality. Answering questions provided by the formative assessment might provide insight to what extent the concepts, associated with the real-world question, are understood by the students. Thus, the teacher can adjust his teaching specifically to difficulties perceived. Before a new sprint starts, students reflect on their learning process, that is, they discuss their mutual communication and other obstacles they experienced. During this retrospective phase they choose one specific point they want to improve in the next sprint cycle. After finishing all sprints, the ultimate product is released or a summative assessment is made. So, the objectives of Scrum methodology are: (1) reducing the overwhelming complexity of a real-world question by creating overview and transparency (stand-up ceremony; Scrum board) and dividing the complete assignment into smaller entities (sprints), and (2) visualising students' learning progress and inspection of its quality (review) and reflecting on their learning process and adapting

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to improve mutual collaboration (retrospective). This means that Scrum methodology provides tools that alert both teacher and students throughout the entire process if there are obstacles that might hinder students' learning. In addition, Scrum ceremonies and artefacts might function as scaffolds to support students' learning and might help to deploy the use of metacognitive skills systematically and indirectly create room for the construction of knowledge structures. In this way, the objectives of Scrum methodology might enforce students' learning when they work in a socio-constructivist, context-based learning environment.

The role of the teacher using Scrum methodology in context-based approaches

Research has shown that especially innovations which require a shift from a rather directive teaching style, to a more participatory and student-centered teaching style are challenging for teachers to implement (Brush and Saye, 2000). Thus, before implementing Scrum methodology into context-based chemistry classrooms, a closer look to specific factors that hinder or facilitate the implementation of context-based approaches, is necessary. Several studies suggest that the following conditions play a key role in the implementation of context-based approaches: (1) teachers should understand the real-world question and the underlying concepts themselves; (2) their beliefs about education should align with the rationale behind the context-based approach and should be supported on the big picture as they develop context-based materials (Prins *et al.*, 2018); (3) they should possess skills necessary to create a context-based learning environment with a focus on monitoring students' learning process as well as guiding and scaffolding their learning progress with appropriate materials (Dori *et al.*, 2018; Sevian *et al.*, 2018); (4) they should be able to develop adequate assessments appropriate for context-based learning environments; (5) they should be able to adapt their teaching to the specific needs of their students, elicit and pay special attention to frequently asked questions and their educational level (Brush and Saye, 2000; Vos *et al.*, 2011; Hugerat *et al.*, 2015; Taconis *et al.*, 2016; Habig *et al.*, 2018; Swirski *et al.*, 2018).

Scrum methodology could potentially support teachers in four of these conditions. Obviously, the first condition-basically about the quality of teachers' subject matter knowledge—is not affected by this project management framework. However, Scrum methodology offers a ceremony in which teachers are challenged to explain why the concepts involved in the project could be meaningful for the students. Secondly, if teachers' beliefs are not aligned with the rationale behind context-based approaches caused by feelings of uncertainty how to guide the students, the ceremonies and the clear structure of Scrum methodology might support teachers in changing their behaviour (condition 2 and 3). This suggests that Scrum might contribute to teachers' didactical expertise, which can be defined as knowledge and skilled use of teaching approaches that guide teachers' planning, execution and evaluation of classroom actions (Beijaard *et al.*, 2000, p. 751; Vermunt *et al.*, 2017, p. 145). Especially in student-centered learning environments, such as context-based approaches, where students typically work collaboratively in small groups, didactical skills, such as guiding, monitoring and facilitating students through the entire learning process, are important aspects of teachers' didactical expertise (Vermunt *et al.*, 2017).

Scrum methodology explicitly supports teachers with the fourth condition by introducing a review phase in the form of a formative assessment at the end of each sprint cycle. These reviews evoke feedback and might support teachers in focusing on the specific needs of their students (condition 5). Reviews reveal misconceptions in an early stage, providing opportunities for students to discuss challenging concepts with their teacher or with team mates. In addition, the retrospective phase, in which students reflect on issues concerning collaboration, communication and their learning approach, reveals problems in an early stage. Retrospectives create opportunities for the teacher to discuss and reflect with their students on motivational issues and how to overcome hindrances perceived, such as collaboration problems within teams. Review and retrospective invite teachers to discuss and reflect with their students on conceptual problems, learning strategies, motivational issues, and how to overcome hindrances perceived, *e.g.*, concerning collaboration in their team.

Both reviews and retrospectives require that teachers have specific subject matter expertise and pedagogical expertise. Subject matter expertise refers to teachers' knowledge of the subject that enables them to deploy appropriate learning tasks, elucidate subject material and diagnose students' misconceptions. Pedagogical expertise refers to the social and emotional dimensions of learning, and focuses on how teachers approach their students. It encompasses sincere interest in what is going on in their minds, motivational and personal issues (Beijaard *et al.*, 2000; Vermunt *et al.*, 2017).

Thus, the ceremonies, roles and artefacts of Scrum methodology might encourage teachers to apply *subject matter expertise*, their *didactical expertise* and *pedagogical expertise* in a suitable way to scaffold students' learning in a context-based learning environment, and thus shape teachers' classroom behaviour.

Research questions

Although several studies focus on how teachers implement context-based approaches in chemistry classrooms (King, 2007; Avargil *et al.*, 2012; Vos *et al.*, 2011; Taconis *et al.*, 2016) research on tools to support teachers in context-based learning, is scarce, although there is a recent example (Prins *et al.*, 2018). In a pilot study, we presented the experiences of three teachers, who implemented Scrum methodology in their context-based chemistry classes as an illustration of its theoretical benefits for educational practice (Vogelzang *et al.*, 2019).

The current study explored the actual implementation of Scrum methodology by a different group of teachers in secondary chemistry classrooms, in depth. More specifically, the study aimed to examine the following research questions (RQ): (1) what is the role of teachers' subject matter expertise, didactical expertise and pedagogical expertise in the implementation process;

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(2) which experiences and challenges facilitate or hinder teachers during the implementation of Scrum methodology and (3) what are teachers' experiences with Scrum methodology as a support framework to teach a context-based chemistry course.

Method

Participants and context of the study

Twelve teachers (3 female; 9 male), who did not participate in the pilot study mentioned before (Vogelzang *et al.*, 2019), voluntarily participated in a professional development program to introduce Scrum methodology in their chemistry classroom. All were experienced teachers with at least five years of teaching practice. They responded to an email-invitation, written by the first author, and distributed by teacher trainers of several educational institutions. They had experience with teacher-centered learning environments as well as with context-based, student-centered learning environments. Teachers worked at different schools from all over the Netherlands. Their classroom compositions differed from 20 to 32 students. Student ages were between 15 to 17/18 years. Students worked on a variety of chemistry topics, including redox-chemistry, green chemistry, polymers and water. For example, in one of classes students studied the impact of polymers on society as well as the forming of thermoplastics and cross-linked thermosets on micro-level. In another class, students worked on redox-chemistry. The teacher challenged his students to design and build a battery suitable to drive a small electric toy car. In two sprints, they studied redox-reactions, electrochemical cells and underlying concepts, according to the 'need-to-know' principle. After each sprint cycle they checked their understanding during the reviews phase. In the third sprint, students became aware of environmental issues connected to redox-chemistry and finally they were invited to build their own battery. Prior to the lessons the teacher developed a product-backlog, reviews, and retrospectives and he organized scrum boards. During the lesson series he monitored students' progress, answered questions and facilitated their learning. In all classes the mastery of concepts was measured with traditional summative assessments.

Nine teachers attended five sessions of 4 hours each on Scrum methodology over a 9 months period. Three teachers missed one session. Their school boards fully agreed and paid for the professional development program. Sessions were presented by a chemistry teacher who had introduced Scrum methodology, a few years ago, in his own context-based chemistry classes. Nowadays, he is the owner of a small company, which provides professional, and certified, Scrum trainings to teachers. Professional development sessions were organised aligned with some principles provided by Fishman *et al.* (2003) and Simon and Campbell (2012) and consisted of (1) conceptual input underlying Scrum methodology, (2) exercises, (3) time to share and reflect on both positive and negative experiences, and (4) feedback from colleagues. After finishing the professional development program, the participants decided to continue to meet on a less regular basis, to exchange educational materials, such as formative assessments, suitable for their chemistry lessons.

The research was carried out following the guidelines for research ethics and integrity of Leiden University. Participating teachers and their principles provided explicitly their informed consent.

Data collection. Four types of data have been collected: interviews, researcher's field notes made during sessions of the professional development program, a reflection written by each participant on the (dis)advantages of Scrum methodology and a questionnaire. The questionnaire revealed the role of teachers' subject matter expertise, their didactical expertise and their pedagogical expertise (RQ 1). Interviews, field notes and the written reflections were used to get insight in teachers' experiences with Scrum methodology in general (RQ 3) and challenges that facilitated or hindered the implementation (RQ 2). In the pilot study, only data were used obtained during interviews, in which teachers reflected on their experiences (Vogelzang *et al.*, 2019).

Interviews, field notes and teachers' written reflections. Between the fourth and fifth session of the professional development program, the first author conducted semi-structured interviews of 35–50 minutes with each teacher. These interviews were held at the school of the interviewee. The main objective was to get insight in implementation issues and teachers' experiences with Scrum methodology. Each interview was structured according to the following questions:

- What was your motivation to implement Scrum methodology in your chemistry classroom?
- What factors hinder or facilitate the implementation of Scrum methodology?
- Did Scrum methodology affect your teaching style? If yes, how?
- What is your opinion about the different aspects of Scrum methodology (stand-up, sprint, review, retrospective *etc.*)?
- Will you use Scrum methodology in future lessons? Why?

During the professional development sessions, the participating teachers were asked to write down their positive and negative experiences in a few keywords. Subsequently they were invited to share and reflect on these experiences. Meanwhile the first author completed field notes with emphasis on facilitating and hindering factors. During the last professional development session, all teachers were asked to write a reflection on the advantages perceived and disadvantages of Scrum methodology. Finally, they reflected on the question whether they would use Scrum in future lessons.

Questionnaire. The participants completed a questionnaire, originally developed by Beijaard *et al.* (2000). Core concept in this questionnaire was teachers' professional identity, which according to Beijaard *et al.* (2000, p. 751), is influenced and shaped by teachers' *subject matter expertise*, their *didactical expertise* as well as their *pedagogical expertise*. In addition, they argued that teachers' professional identity is influenced and shaped by the *context* in which they teach, by *teaching experiences*

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during their career, and their *personal biography*. All these six aspects were explored in the questionnaire.

The questionnaire comprised three parts. The first part consisted of general questions about teacher background (age, years of experience). In order to be able to interpret the data of the twelve participating teachers, 63 other chemistry teachers completed the questionnaire. These teachers were selected from the personal network of the first author and worked at different secondary schools all over The Netherlands. Due to the fact that teachers' professional identity is subject to change—especially at the start of their career—we deleted the data of six novice teachers of the 63 chemistry teachers, because they had less than five years of teaching experience, which is a common cut-off point (Canrinus *et al.*, 2012). Participants varied in age and experience, see Table 1. Most teachers of the comparison group (68%), as well of the participating group (58%) taught upper as well as lower grades at their secondary school. The majority of teachers (comparison group: 81%; participating group: 100%) had attended a university teacher training program. Of the teachers of the comparison group 44% were female, of the participating group 25% were female.

In the second part of the questionnaire, teachers answered 18 items (four-point Likert scale, ranging from 1: not applicable, to 4: completely applicable). Six items on subject matter expertise, didactical expertise and pedagogical expertise, respectively. Three examples of items are:

• a subject matter item: ''I am interested in new developments within my field of expertise (chemistry)''.

• a didactical item: ''I evaluate the quality of my teaching on a regular basis''.

• a pedagogical item: ''Creating a climate in the classroom in which students feel safe and respected is an important principle in my lessons''.

In Table 2, we present the scores on teachers' subject matter expertise, didactical expertise and pedagogical expertise. After an item-total reliability test, one identity item from part 3, concerning subject matter was omitted. The reliabilities found, were higher than the ones presented by Beijaard *et al.* (2000). Univariate analysis of variance revealed no difference between comparison and participating group (Table 2). Therefore, we consider the three types of expertise of our sample of twelve teachers representative for teachers in secondary chemistry education.

The third part of the questionnaire also comprised 18 items, six items for three additional factors that influence teachers' professional identity *i.e.*, teaching context, teaching experience and biography. Again, a four-point Likert scale was used (ranging from 1: disagreement to 4: complete agreement). A high score on these items means that the respondent agrees that this factor plays an important role for their professional identity. Some examples of items are:

• a teaching contextual item: ''Close cooperation with colleagues is very important for me to function properly as teacher.''

• a teaching experience item: ''My teaching experiences have contributed significantly to my teaching style.''

• a biography item: ''My teaching style is strongly influenced by excellent teachers in my youth.''

In Table 3, we show teachers' perceptions of influencing factors (teaching context, teaching experience and personal biography). After an item-total reliability test, three items from part 3 were omitted. Two of the omitted items concerned teaching experience and one item concerned biography. The reliabilities found were similar with values found by Beijaard *et al.* (2000). Univariate analysis of variance revealed no difference between comparison and participating group (Table 3). Therefore, we consider these three additional factors of our sample of 12 teachers representative for teachers in secondary education.

Table 1 Characteristics of participating teachers

Participating group (N = 12)	N	%	Comparison group (N = 57)	N	%
Years of teaching experience			Years of teaching experience		
5–10	3	25	5–10	19	33
11–20	6	50	11–20	19	33
21–30	2	17	21–30	12	21
31–40	1	8	31–40	7	12
Age			Age		
< 40	3	25	<40	7	12
41–50	6	50	41–50	29	51
>51	3	25	>51	16	28
Not provided	—	—	Not provided	5	9
Education			Education		
University training program	12	100	University training program	46	81
College training program	—	—	College training program	11	19
Teaching			Teaching		
Upper as well as lower grades	7	58	Upper as well as lower grades	39	68
Upper grades	5	42	Upper grades	13	23
Lower grades	—	—	Lower grades	5	9
Gender			Gender		
Female	3	25	Female	25	44

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Table 2 Comparison of Beijaard *et al.* (2000) and this study for subject matter expert, didactical expert and pedagogical expert. Data derived from the questionnaire, part 2

	Subject matter expert (5 items)		Didactical expert (6 items)		Pedagogical expert (6 items)	
Part 2	Cronbach's α	Mean (SD)	Cronbach's α	Mean (SD)	Cronbach's α	Mean (SD)
Beijaard *et al.* (2000) (N = 80)	0.62	3.13 (0.54)	0.58	2.84 (0.44)	0.68	3.22 (0.46)
Comparison group (N = 57)	0.65	3.18 (0.45)	0.70	2.91 (0.43)	0.81	3.03 (0.48)
Participating group (N = 12)	0.72	3.35 (0.45)	0.75	2.91 (0.48)	0.72	3.29 (0.42)
No statistical differences between comparison and participating group		Sign. 0.101		Sign. 0.500		Sign. 0.202

Table 3 Comparison of Beijaard *et al.* (2000) and this study for teaching context, teaching experience and biography of the teacher. Data derived from the questionnaire, part 3

	Teaching context (6 items)		Teaching experience (4 items)		Biography of teacher (5 items)	
Part 3	Cronbach's α	Mean (SD)	Cronbach's α	Mean (SD)	Cronbach's α	Mean (SD)
Beijaard *et al.* (2000) (N = 80)	0.76	3.12 (0.60)	0.64	2.41 (0.58)	0.59	2.47 (0.56)
Comparison group (N = 57)	0.70	3.18 (0.46)	0.65	2.49 (0.54)	0.57	2.38 (0.49)
Participating group (N = 12)	0.88	3.31 (0.61)	0.71	2.68 (0.71)	0.63	2.44 (0.54)
No statistical differences between comparison and participating group		Sign. 0.613		Sign. 0.487		Sign. 0.921

Data analysis. The interviews were transcribed verbatim and were sent to the teachers for approval. Analysing these data revealed teachers' successes and the challenges they met during the implementation process. A simple rubric, comprising three categories, 'success', 'moderate', and 'challenge' was used. Relevant keywords and phrases in the interviews were assigned to the corresponding categories. For example: ''My students often use their Scrum board'' was assigned to 'success' and received three points. A phrase in which the teacher explained why he was not fully satisfied by the implementation was assigned to 'moderate' and awarded with two points. A characteristic example: ''I implemented the stand-up ceremony. However, after a few lessons my students preferred a 'sit-down ceremony', which is less energizing than a stand-up.'' A quote like: ''I did not use the retrospective ceremony; however, I will try in the future.'' was assigned to 'challenge' and was awarded one point. Number of statements investigated per teacher varied from 17 to 38, with an average of 27 statements. A weighted average of all statements was calculated for each individual teacher. The three teachers with the highest scores were characterised as 'top-teachers' (Adrian, Paul, Rodney (pseudonyms)). Their average score varied from 2.6–2.8. The three teachers with the lowest average scores, varying from 1.6–1.7, were labelled as 'growth-teachers' (Michael, Sheila, Nigel (pseudonyms)). The other six teachers with scores varying from 1.8–2.4, were characterised as 'moderate'. Their statements did not provide extra information that was not present in the data of top-teachers or growth-teachers.

Statements made during the professional development sessions, in which teachers characterised their implementation process with illustrative quotes based on reactions of students, parents or the school board, were explored to find potential discrepancies with statements made during the interviews. 'Top-teachers' did not mention resistance against Scrum methodology in their classes, whereas 'growth-teachers' reported serious counter pressure from students and sometimes parents, suggesting that the distribution of teachers to the categories 'top-teachers' and 'growth-teachers', is appropriate. Teachers allocated to the category 'moderate' mentioned a variety of both facilitating and hindering factors and were less pronounced in how their students perceived Scrum methodology. Both 'top-teachers' and 'growth-teachers' will be portrayed in the result section, because ''there is much to be learned from the particulars'' (Helms, 1998, p. 832).

Subsequently, an additional analysis of the quantitative data obtained from part 2 of the questionnaire was performed. Average scores of 'top-teachers' as well as 'growth-teachers'—on the six different aspects measured by the questionnaire—were calculated, to find specific trends that might explain the observed implementation differences between 'top-teachers' and 'growth-teachers'.

Data collected in the last professional development session focused on perceived advantages and disadvantages of Scrum methodology and were kept apart from the other qualitative data. How often a specific advantage or disadvantage was mentioned by the teachers led to a ranking order, indicating what aspects of Scrum methodology might stimulate or hinder its implementation.

Results

This study aims to examine: (1) the role of teachers' subject matter expertise, didactical expertise and pedagogical expertise in the implementation process; (2) the experiences and challenges teachers encounter during the implementation of Scrum methodology and (3) teachers' experiences with Scrum methodology as a suitable support framework when they teach a context-based chemistry course.

The role of teachers' subject matter expertise, didactical expertise and pedagogical expertise in the implementation process

Data from part 2 of the questionnaire showed differences in didactical and pedagogical expertise of 'top-teachers' and

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Table 4 Scores for subject matter expert, didactical expert and pedagogical expert as well as three other influencing factors

		Subject matter expertise (5 items)	Didactical expertise (6 items)	Pedagogical expertise (6 items)	Teaching context (4 items)	Teaching experience (6 items)	Biography (5 items)
	N	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Participating group	12	3.35 (0.45)	2.91 (0.48)	3.29 (0.42)	3.31 (0.61)	2.68 (0.71)	2.44 (0.54)
'Top-teachers'	3	3.60 (0.40)	3.56 (0.19)	3.83 (0.00)	3.50 (0.60)	3.17 (0.76)	2.73 (0.50)
'Moderate-teachers'	6	3.30 (0.35)	2.83 (0.37)	3.28 (0.23)	3.33 (0.28)	2.54 (0.25)	2.47 (0.52)
'Growth-teachers'	3	3.47 (0.31)	2.52 (0.46)	2.78 (0.10)	3.39 (0.67)	2.96 (0.36)	2.37 (0.15)

'growth-teachers', the former scoring substantially higher than the latter (Table 4).

To understand these differences, we explore these two groups in depth, using the qualitative data gathered during the interviews, and professional development program. In the following sections experiences and challenges encountered by 'top-teachers' and 'growth-teachers' are presented in the form of portraits. Paraphrases of key statements and short characteristics of both the classroom climate and the relationship between teacher and students are offered in Table 5 for 'top-teachers' and in Table 6 for 'growth-teachers'.

Experiences and challenges encountered during the implementation of Scrum methodology

Portraits of top-teachers. *Paul*, a teacher with more than 30 years of teaching experience, stated that he was waiting for a methodology to scaffold context-based learning environments. He was disappointed about the results of a large educational reform around the year 2000 to improve students' ownership and self-regulation. According to Paul "teachers were not able to facilitate students' learning in an appropriate way, because they did not have the tools necessary to mentor their students. Scrum methodology provides such tools. Ceremonies such as stand-up meeting and reviews keep students on track. The Scrum board is an appropriate artefact to get overview". Paul illustrates his enthusiasm about Scrum methodology with examples from his lessons: "My students are enthusiastic, show more commitment and—to be honest—sometimes panicked". Paul elaborated students' 'panic': "Students become aware of their own responsibility, and sometimes they do not know how to proceed". He continues: Scrum lessons are more "sociable" and it is easier to "contact your students". And: "results (on a summative assessment) were really good". He reflected on the implementation process. "I asked students for feedback, and when they told me that they needed some extra explanation, I decided to arrange a moment in the next lesson to respond to difficulties my students experienced". Despite his enthusiasm some students were sceptical. An illustrative quote: "One of my students doubted if Scrum methodology would help her to understand chemistry. She perceived chemistry as a difficult subject and felt uncertain. I said: "Trust me, I know exactly what I am doing. You will experience that Scrum methodology is an additional help during the learning process. I guarantee that you will master the chemistry concepts. If necessary, I will explain difficult topics to you and your classmates. You're welcome to ask your questions. What will be your next step...?"" Now, Paul is involved in introducing Scrum methodology in his school.

Rodney, teaches chemistry in a small town in the western part of the Netherlands. He has more than 15 years teaching experience. At first, he was sceptical about the potential benefits of Scrum methodology. He stated: "Using a specific methodology is not a goal in itself, it should be a—preferably invisible—scaffold. Teaching chemistry is about chemistry and its underlying concepts. It is not about time-consuming ceremonies, reviews and retrospectives". However, he wanted to experience the effect on students' behaviour and learning from the explicit reflection moments provided by Scrum methodology as well as the impact on his own teaching style. Rodney emphasized that Scrum methodology asks a "lot of preparation. As a teacher, you

Table 5 What 'top-teachers' say

What 'top-teachers' say:
Scrum provides tools to facilitate students' cognitive and metacognitive development.
Scrum visualises students' learning process and their learning progress.
Consequently, adjusting to students' specific needs is easier.
Students' feedback improves the quality of your teaching.
The *relationship* between teacher and students can be characterized with: "together".
Classroom climate is somewhere on a scale between teacher-centered and student-centered and can be characterised with: "shared control".

Table 6 Essentials according to 'growth-teachers'

Essentials derived from interviews with 'growth-teachers':
Scrum is a complex framework and implementing the ceremonies as intended is difficult.
Scrum requires sophisticated organizational skills.
Relationship between teacher and students can be characterized with: "opposing positions".
Classroom climate is more student-centered than teacher-centered and can be characterised with: "students in charge".

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have to organise Scrum boards, develop formative assessments and so on''. He described that starting with Scrum methodology was stressful: ''the introduction of the methodology including all ceremonies is time-consuming''. However, he experienced that his students worked very hard on the project. He said: ''Scrum provides handles that enables me to discuss subject knowledge as well as learning strategies and planning. A Scrum board is a 'living' document and makes it easy to adapt your planning to changing circumstances''. ''It helps students to direct their learning'', and ''what I see, students are more actively involved, and try to reach the learning goals within time. And when I am discussing a topic with one of the groups, the other groups continue their work. That's a welcome benefit!'' Especially the reviews—which evoked feedback among students as well as from students to teacher—were appreciated by Rodney as indicators of students' learning progress. He experienced that some students perceived difficulties with the first review. To overcome this potential obstacle, he immediately improved the following reviews and developed two levels: basic and expert. To his surprise most students tried the expert level. Rodney stated: ''the experience of success positively impacts students' engagement and learning''. And: ''for me as a teacher it is easier to differentiate, (...) to adjust to the specific level of students''. Successful implementation of Scrum depends—according to Rodney—on the teacher. ''You have to be a reflective, open-minded teacher. If you are forced to implement Scrum, you are without prospects''. It is crucial to possess ''the ability and courage to discuss the implementation process with your students''. You should use ''their feedback to improve your teaching''.

Adrian, an experienced teacher introduced Scrum methodology in all his six classes. ''The methodology is used in companies in which our students will work in the future. Scrum visualizes progress and reveals problems in an early stage. Scrum methodology is invaluable for stimulating the use of 21st century skills such as collaboration and promoting deep learning''. Adrian described his experiences: ''When students are familiar with Scrum, they will start autonomously''. As a teacher ''you are able to provide appropriate feedback on different levels. (...) Subject matter as well as on learning strategies and on the personal qualities students bring to the classroom''. After a while he decided, for organizational reasons, to return temporarily to a more teacher-centered teaching style. However, his students asked him to reintroduce Scrum methodology. Mostly because of the autonomy they had experienced during the lessons based on Scrum methodology. A few students preferred the teacher-centered teaching style for a simple reason: they didn't like that they had to work harder during Scrum lessons. According to Adrian, it is important to have a ''meaningful real-world question and clear learning goals. You have to share these goals with your students''. In this way students experience ''the added value of Scrum methodology''.

Portraits of growth-teachers. *Sheila* had taught chemistry in a small town near Amsterdam for fifteen years. Sheila was looking for a method to increase students' engagement and ownership: ''My students just sat back and were really relaxed....'' She continued: ''Students should take responsibility for their own learning and for their team mates' learning. I think that Scrum offers the tools to structure and direct students' learning. (...) Scrum provides ceremonies to improve collaboration among students because your school life is more than great grades on tests, it is also about mutual communication, collaboration, listening to each other, helping each other... you should learn these skills during your school career''. Sheila reported resistance and serious opposition of her students against the use of Scrum methodology. After a few weeks parents and school board contacted her. Some students complained that they did not receive any explanation about the chemistry concepts. Other students showed resistance against the ceremonies and Scrum artefacts and some students did not cooperate in their group. Reviews in the form of formative assessments were not appreciated. Apparently, because students did not recognize the concepts necessary to answer the questions. In addition: students expected that the teacher checked all their answers. Sheila said: ''...checking all formative assessments is time consuming and all information and all answers are available for the students''. She tried to stimulate students' ownership for their learning and replied to her students: ''These are the questions, here are the answers, it's your responsibility to prepare for the final assessment''. Although Sheila persisted in working with Scrum methodology, she finally skipped the method.

Michael had worked as a teacher for seven years in a town in the western part of the Netherlands and was invited by colleagues to participate in the personal development program on Scrum methodology. Michael stated that an important aspect of students' learning is exercising with problem solving skills. ''Students should learn to solve complex problems. Finding answers themselves is an important skill. Learning is about ownership. Thus, in my opinion, context-based learning should be part of students' learning. Facilitating context-based learning is challenging for teachers. I think, Scrum methodology creates an environment, that directs students' learning and stimulates students to reflect on their learning strategy''. However, Michael stated: ''(...) in my classes I see a dichotomy. Most students embrace the Scrum method. Although there are still students who show resistance. 'Why should we work like this? It's time consuming. It's your duty to explain this difficult exercise on the blackboard'. And then it is very difficult to use Scrum ceremonies as intended''. Some students do not see the ''added value of Scrum (...). Thus, their commitment with Scrum ceremonies is low''. Later he confessed: ''To be honest: Scrum methodology is rather complex. I do not follow all the ceremonies in an appropriate way. Nevertheless, I will continue to use Scrum. Some parents, who use Scrum in their daily work, stimulate me to continue''. And in one of the professional development sessions Michael said: ''I have to exercise, exercise and exercise (...)'' and ''(...). I have to talk with my students to find out what they need''.

After a scientific career in a highly sophisticated chemistry laboratory—where in some sections Scrum methodology was used—*Nigel* moved to secondary education. Improving his

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coaching skills was one of the objectives to participate in the professional development program. He was interested in scaffolds provided by Scrum methodology to adjust his teaching to students' needs on both subject matter and learning strategies. Nigel noticed that the introduction of Scrum methodology gave him the opportunity to discuss the chemistry concepts in depth with the groups. In addition, using Scrum provides deeper insight in students' concerns, because "you walk around your class, while your students are at work". Nigel reported some serious implementation problems. He explained that implementing Scrum methodology requires sophisticated organisational skills. Before starting a lesson, there is a lot of preparatory work to be done. Nigel: "Sometimes it happens that I have to arrange a few things and then... just let it go... Well..., then you have to accept that your students do not execute the ceremonies, accompanying Scrum methodology, perfectly". Providing the teaching materials to his students too late, caused serious problems, and resistance. At the end of the interview Nigel reflected on the professional development sessions on Scrum methodology. "When we were discussing implementation issues, I realised that I have to learn a lot. I have to change my teaching behaviour to a more active style. (...) I have to follow the developments in the different groups more closely. I have to monitor students' learning progress more intensely, instead of reclining or whatever... (...) I have to think about the next step and ask myself questions like: 'Do I have to arrange something?', 'Is it necessary to give an extra explanation?', 'How do I improve my coaching skills?' There is a lot to be gained..." Despite the implementation challenges, Nigel is convinced that he will continue to use Scrum methodology in the future.

Perceived (dis)advantages of Scrum methodology according to the teachers

The third aim of the study was to examine to get insight in teachers' experiences with Scrum methodology. Their responses on what they experienced as (dis)advantages of Scrum methodology are summarised in Table 7. We did not find major differences between top-teachers and growth-teachers with respect to perceived (dis)-advantages with Scrum. Therefore, we combined the statements of all twelve teachers.

Interestingly, all participating teachers mentioned the reviews in their written reflections. Reviews in the form of formative assessments are highly appreciated. Reviews provide teacher as well as students insight in students' learning progress. In addition, a Scrum board was recognised by most teachers as a useful tool to visualise students' planning and progress. Scrum stimulates to elaborate the learning objectives. On the other hand, teachers' written reports clearly revealed that Scrum methodology in itself is rather complex and time-consuming for both teachers and students. Especially at the beginning it creates a substantial cognitive load for students. If students are not familiar with the methodology and when the added value is not seen, there is a chance that students will show resistance, resulting in a classroom environment where focus is distracted easily from learning.

Discussion

The first research question of this study focused on the role of teachers' expertise during the implementation of Scrum methodology. Following Beijaard *et al.* (2000), we distinguished three different types of expertise, as part of teachers' professional identity: subject matter expertise, didactical expertise and pedagogical expertise. Besides that, we distinguished three other factors: teaching context, teaching experiences and personal biography and five conditions that might influence the implementation process: (1) understanding of the real-world question; (2) alignment of teachers' beliefs with the rationale behind context-based approaches; (3) possessing skills to create an appropriate learning environment; (4) adequate assessment procedures and (5) the ability to adapt teaching to the specific needs of the students.

Table 7 (Dis)advantages of Scrum methodology as perceived by the twelve participating teachers (numbers in brackets refer to how often the particular statement was made among the twelve teachers)

Perspective	Advantages	Disadvantages
Teacher	Reviews in the form of formative assessments are excellent to get insight in students' learning process (12).	It takes time to become familiar with all ceremonies, roles and artefacts (7).
	A Scrum board visualises students' learning progress and process (8).	Ceremonies are time-consuming and overtime it is difficult to follow the accompanying procedures in an appropriate way (7).
	Misconceptions and learning obstacles become visible in an early stage (8).	If the added value of Scrum methodology is not seen, students will show resistance (5).
	The ceremonies, roles and artefacts of Scrum methodology have added value when complex educational materials are used (6).	Using Scrum asks a lot of preparation time (6).
	Scrum forces to think about learning objectives (5).	Scrum requires excellent organizational skills (4).
	Scrum methodology provides a clear structure (4).	Scrum is a project management framework and is inappropriate for training of rather simple exercises (1).
	Scrum methodology is used in many companies and businesses, school should prepare students for this (1).	
Students	If students are familiar with Scrum methodology, they work hard (6).	Scrum methodology with all its ceremonies, roles and artefacts is in itself rather complex (7).
	They take responsibility for their team mates' learning (5).	
	Scrum is beneficial to take ownership (4).	
	Scrum supports self-regulated learning (3).	
	Students perceive a lot of autonomy (3).	

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Both 'top-teachers' and 'growth-teachers' acknowledged the importance of subject matter expertise. Yet, the similar scores for 'top-teachers' as well as 'growth-teachers' on subject matter expertise (see Table 4), indicated that a solid subject matter expertise is not the *distinguishing* key factor to implement Scrum methodology successfully. However, without doubt, teachers' subject matter expertise is invaluable in both teacher-centered and in student-centered learning environments. A deep and full understanding helps explaining concepts at a high-quality level and is considered as a prerequisite to diagnose students' misconceptions adequately (Beijaard *et al.*, 2000; Vermunt *et al.*, 2017). In addition, implementing Scrum methodology does not imply that teachers do not have to explain difficult concepts to their students. Scrum methodology is not a substitute for teachers' subject matter expertise. On the contrary, it is still important that a teacher understand the ins and outs of the real-world question (condition 1). One of the 'growth-teachers' received serious complaints from students, and school board, because she did not provide enough explanation to her students. One of the 'top-teachers' emphasized that the circumstances created by Scrum methodology helped him to discover misconceptions in an early stage, enabling him to deliver and explain chemistry concepts desired by the students.

Obviously, remarkable differences concerning teachers' didactical expertise were visible in the data, with 'top-teachers' scoring substantially higher than 'growth-teachers' (Table 4). A high score on didactical expertise indicates that a teacher is aware that secure planning, the use of a variety of teaching approaches, and evaluation of their classroom actions are important aspects of his professional identity (Beijaard *et al.*, 2000). In addition, a high score suggests that a teacher perceives to be able to deploy these skills in the classroom, increasing the chance that new innovative teaching approaches will be implemented successfully. Indeed, interviews and field notes revealed that the 'top-teachers' had smooth classroom routines, although Scrum methodology requires ''a lot of preparation'' (Rodney). 'Growth-teachers' experienced difficulties with ''organisational aspects'' (Nigel) and with using the ceremonies in an appropriate way (Michael). Vermunt *et al.* (2017, p. 145) emphasize that teachers' didactical expertise is especially involved when teaching shifts from a teacher-centered approach to a more student-centered approach. Teachers' role shifts from almost solely 'transmitting subject knowledge' to a more complex role in which they 'facilitate students' learning', that is, monitoring learning progress and process and adjusting to the specific needs of the students. This requires that teachers' beliefs are aligned with the rationale behind context-based approaches and Scrum methodology (condition 2).

The same is true for teachers' pedagogical expertise. Again, a remarkable difference was found between 'top-teachers' and 'growth-teachers'. 'Top-teachers' ask for feedback from their students, and immediately adapt their teaching (Paul/Rodney), whereas 'growth-teachers' characterize students' feedback as complaints. Especially in new circumstances continuous adjustment to students' concerns, is crucial (condition 3 and 5). Keywords are mutual respect, careful listening, sincere attention, transparent and fast communication and a safe learning environment in which failure is an option. In such classrooms students and teacher are connected and students feel free to share their scepticism about Scrum methodology as well as their concerns about chemistry concepts they have to master.

With respect to the factors that influence teachers' implementation of Scrum (teaching context, teaching experiences, and personal biography (Table 4)), differences between 'top-teachers' and 'growth-teachers' were much smaller, suggesting that the role of these factors during the implementation process, presented in this study, is secondary. These results were not unexpected, given the fact that all participants are experienced teachers working in schools in which the school board encouraged and supported them to participate in the professional development sessions to implement Scrum methodology. The rather small differences on scores on teachers' personal biography for 'top-teachers' and 'growth-teachers', suggest that critical events, unintended, unplanned and uncontrollable circumstances in a classroom that have an enormous impact on classroom climate and on students' learning (Woods, 2012), did not influence the implementation.

Thus, the results of this study emphasize the relevance of both teachers' didactical and pedagogical expertise. Teachers who successfully implemented Scrum methodology in their context-based learning environment scored much higher on these factors than teachers struggling with the implementation, suggesting that the scores might be related to the quality of the implementation of Scrum methodology. These results perfectly fit with strategies of effective teachers in general (Mitchell, 2014; Muijs and Reynolds, 2018) and strategies of effective teachers in context-based learning environments in particular (Vos *et al.*, 2011; Taconis *et al.*, 2016). Effective teachers possess excellent organizational skills. They have clear learning objectives for their lessons and make sure their students understand them. Resources are available, they develop adequate assessments and they have well-established and smooth classroom routines. Students work collaboratively, receive evaluative feedback from other students and teacher and spend more time learning. The learning environment can be characterized as a 'community of practice' in which students develop their understanding through interactions with context, tasks and their teacher (Gilbert *et al.*, 2011, p. 821). These typical didactical aspects of teaching are accompanied by pedagogical aspects such as a positive relationship with students, ongoing dialogue and creating happy students with mutual respect and positive expectations for achievement. The relationship between students and teacher can be characterized by 'together' or 'connected' (Muijs and Reynolds, 2018, p. 93). In addition, effective teachers personalize their teaching, and are sensitive to the needs and interests of individual students. Subject matter is still very important to them. Their students are fully involved, they use meaningful, interactive discussions to explain difficult concepts, taking care to work within the 'zone of proximal development' of their students (Gilbert *et al.*, 2011, p. 822; Stronge, 2018, p. 16).

Secondly, we explored the experiences and challenges that facilitate or hinder teachers during the implementation of Scrum methodology. The remarks of the participating teachers

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made during the interviews are completely in line with the characteristics of effective teaching, formulated by Mitchell (2014) and Muijs and Reynolds (2018). 'Growth-teachers' emphasized that the implementation was hindered by organizational issues, including that resources were not available at the right time. In addition, the data suggest that a positive classroom climate facilitates the implementation (condition 3). 'Top-teachers' reported that they used students' feedback frequently, to adjust their teaching to specific needs of their students (condition 5). Their classes can be characterized with 'shared control'. Both students and teacher contribute to a classroom climate in which feedback on teaching as well as on students' learning occurs continuously. 'Growth-teachers' participating in this study mentioned resistance of students towards Scrum methodology, resulting in opposite positions for teacher and students, which in turn, contributed to a less positive classroom climate.

The last objective focused on teachers' experiences with Scrum methodology. The data revealed a mixed picture, and confirmed interview data obtained in the pilot study, which revealed both enthusiasm and skepticism among the participating teachers (Vogelzang *et al.*, 2019). However, surprisingly, almost all participating teachers stated in the interviews and written report that the advantages of Scrum methodology overrule their disadvantages. All participating teachers agreed that the methodology in itself is rather complex. However, they acknowledged that it is a helpful scaffold when students work on complex real-world questions. It takes time to get familiar with all ceremonies, roles and artefacts. Despite these disadvantages, all teachers stated that Scrum methodology stimulates students to take responsibility and it visualizes the contribution of individual students. Artefacts, such as a Scrum board, provide overview, and reveal students' progress. Especially the systematic use of formative assessments during the review at the end of a sprint cycle is highly appreciated, as it evokes reflection on the quality of students' work and uncovers misconceptions in an early stage (condition 4). This is an important finding. Given the fact that, although formative assessments are associated with positive learning achievements (Andrade and Heritage, 2017; Vogelzang and Admiraal, 2017), its implementation in classrooms is by no means straightforward, even in ideal circumstances (Wiliam *et al.*, 2004). Grob *et al.* (2017) described several challenges when teachers implement formative assessments in their classrooms, including organizational issues such as difficulties with planning and problems to provide feedback just in time. Embedding formative assessment within the clear structure of Scrum methodology might allay these challenges.

Limitations

Teachers opted voluntarily to participate in the study and had, in general, a positive attitude towards Scrum methodology. Therefore, participating teachers might deviate from 'regular' teachers, concerning their motivation or even because they are better teachers. This might be a threat to validity of this study. However, the scores of participating teachers on subject matter expertise, didactical expertise, pedagogical expertise, teaching context, teaching experience and personal biography (Tables 2 and 3) did not deviate from the scores of the comparison group. In addition, given the fact that the data (interviews, questionnaires) yielded a broad variety of views, including skeptical and negative responses, suggests that the results give a realistic view on teachers' perspectives when the implement a new instructional framework, such as the Scrum methodology, in their classroom.

Concluding remarks and future directions

Implementing a project management framework such as Scrum methodology in an educational context such as secondary chemistry classrooms puts high demands on teachers. However, the experiences of the participating teachers in this study reveal that a classroom climate in which teacher and students are working together in a consistent manner is both beneficial for and an important condition for the implementation of Scrum methodology. To achieve such an environment, teachers should deploy their didactical expertise. First, to explain why and how they want to implement Scrum methodology. Secondly, they should accomplish their preparation work, *i.e.*, carefully prepare Scrum ceremonies (stand-up, review, retrospective), and set up the required artefacts (scrum board, product backlog). At the same time, they should use their pedagogical expertise to connect to their students, take their feedback and concerns seriously, and fine-tune the Scrum approach to the specific needs of their students. Although the implementation of Scrum methodology might initially increase the complexity of the learning environment, all participating teachers agree that its clear structure contributes to a learning environment in which students' learning process and their learning progress is more visible. When teacher and students are familiar with Scrum methodology, this might decrease the complexity associated with context-based approaches as used in secondary chemistry education. Empirical evidence to investigate this claim is in progress.

In secondary education, effective teaching with Scrum methodology seem to be at least partly dependent of general teaching quality. Didactical and pedagogical expertise enhances teaching with Scrum: it supports the implementation of Scrum methodology as well as increases its effectiveness, independently of teaching experience and educational context. This would mean Scrum methodology offers possibilities for starting, middle-career and veteran teachers to enhance and enrich their teaching practice.

Conflicts of interest

There are no conflicts of interest to declare.

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