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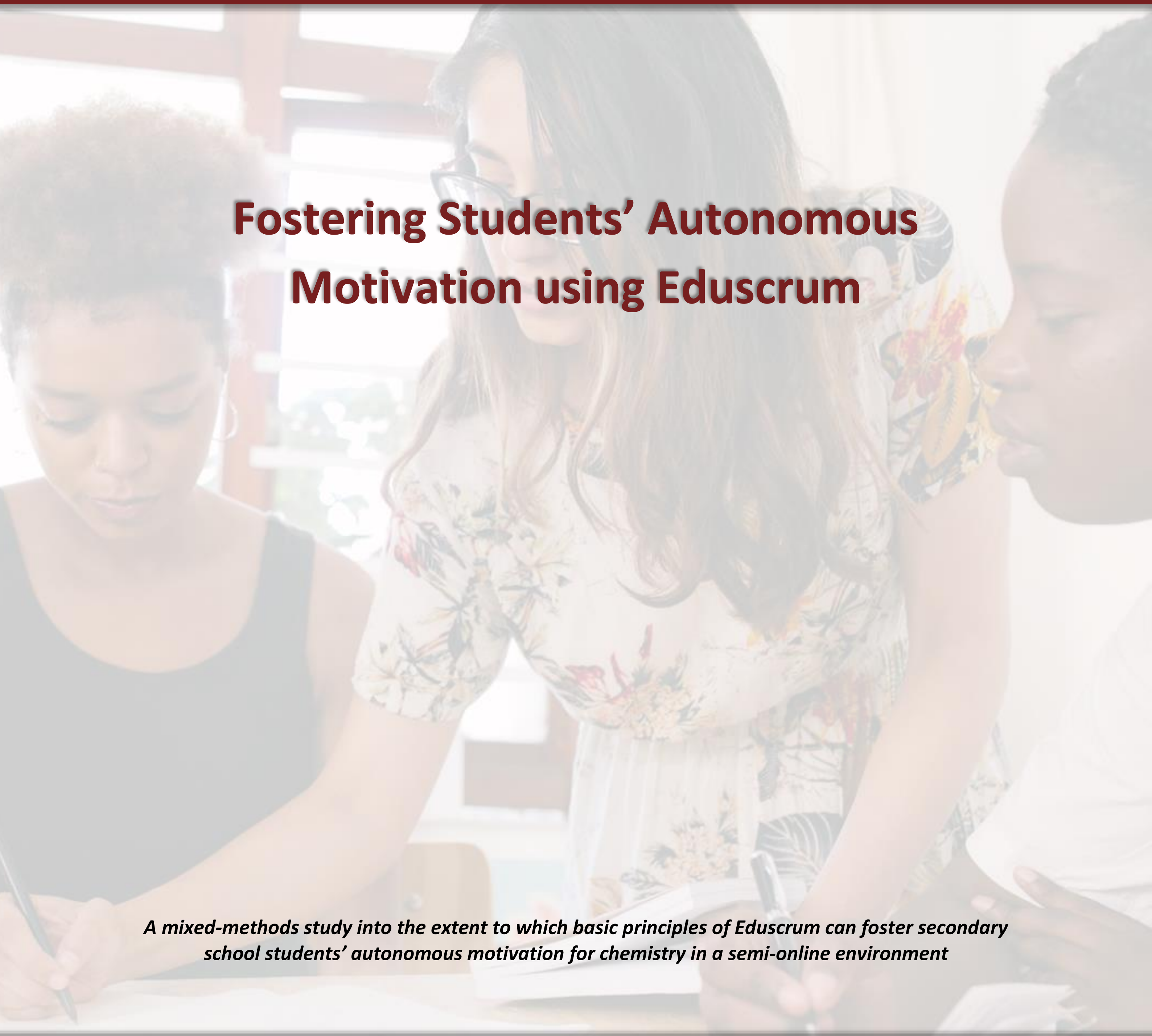

Fostering Students' Autonomous Motivation using Eduscrum

A mixed-methods study into the extent to which basic principles of Eduscrum can foster secondary school students' autonomous motivation for chemistry in a semi-online environment

SCIENCE EDUCATION AND COMMUNICATION
FREUDENTHAL INSTITUTE - UTRECHT UNIVERSITY

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30 ECTS

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Preface

As a teacher I strive for a way of teaching that fosters my students' autonomous motivation for chemistry. This is challenging, because Dutch secondary students' are known for their lack of motivation for STEM subjects. With this study I have investigated how the use of basic principles of Eduscrum can be effective in fostering the student's autonomous motivation for chemistry. This research was conducted as part of the Master Science Education and Communication (Teacher Track) at Utrecht University. I have worked on this Research Project from June 2020 to February 2021, amidst the COVID-19 pandemic that unfortunately interrupted the second iteration. Naturally, perfection was not reached, but I have committedly worked on this project under the motto: "And whatsoever ye do, do it heartily, as to the Lord" – Colossians 3:23a.

I would like to thank Ralph Meulenbroeks for his inspiring supervision throughout the project that clearly showed the meaning of 'practice what you preach.' I am thankful for the opportunity to work on this project under his enthusiastic, connecting guidance with a good balance between autonomy on the one hand and support of competence on the other hand. Furthermore, I would like to thank Arthur Bakker for his instructions and advice on how to conduct a design study, which really helped me.

Without the involvement of the students this research would not have been possible. I would like to take this opportunity to thank them for participating in the study and especially for giving feedback on the Eduscrum design in the focus groups. This has been very important to the study. In addition to that, I would like to thank my colleagues at the Jacobus Fruytier school for giving me the opportunity to conduct my research at the school and for their empathy during the process. Furthermore, I would like to thank my parents for their encouragement and advice during the project and for their patience with my later and later working hours. They will never realise how much their support means to me. Finally, I would like to thank my two co-readers, Willemijn Verzijl and Simone Souër, who provided me with useful feedback.

I am thankful for receiving the health, insight and persistence to finish this project. I hope it will inspire secondary school teachers to support their students' basic psychological needs and foster their students' autonomous motivation for the subject they teach.

Abstract:

Motivation is crucial for education, as it can be considered the driving force behind persistence, retention, achievement and course satisfaction. However, secondary school students have been demonstrating a lack of motivation and engagement, especially for STEM subjects. This situation can be aggravated by the fact, that distance-learning caused by the COVID-19 crisis thwarts one of the main basic psychological needs; the sense of relatedness. In order to attempt to remedy these issues, basic elements of an agile learning technique called Eduscrum are investigated in 9th grade (Havo/VWO 3) secondary chemistry education classes (n=202), the hypothesis being that in accordance with the Self-Determination Theory, Eduscrum fosters the autonomous motivation. The study aims to unveil which mechanisms occur during the process and what parts of the Eduscrum design are most effective. Results were gathered by means of semi-structured focus group interviews and questionnaires. To analyse the data, a mixed methods cross-sectional conjecture mapping approach is used. A paired samples t-test showed that there was a significant gain in the Relative Autonomy Index for the first iteration, indicating a gain in the students' autonomous motivation. The support of the basic psychological needs was reported by the students during focus group interviews. The teamwork, the freedom to schedule tasks and a simple and clear scrum board were reported to be mainly responsible for the increase in the students' autonomous motivation for chemistry.

Keywords: Psychological needs, autonomy, competence, relatedness, intrinsic motivation, cognitive evaluation theory, basic needs theory, self-determination theory, online education, Eduscrum, Scrum, Relative Autonomy Index, autonomous motivation, controlled regulation

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List of abbreviations and glossary

Abbreviations

CAR	Competence, Autonomy and Relatedness
CET	Cognitive Evaluation Theory
EDR	Educational Design Research
IBL	Inquiry-Based Learning
PLOC	Perceived Locus of Causality
RAI	Relative Autonomy Index
SDT	Self-Determination Theory
SRQ-A	Self-Regulation Questionnaires-Academic
STEM	Science, Technology, Engineering and Mathematics

Glossary

Autonomous motivation	State of being (somewhat) internally moved to do something (umbrella term for intrinsic motivation and identified regulation)
Autonomy	A person's opportunity to decide by itself, one of the basic psychological needs
Controlled regulation	State of being (somewhat) externally moved to do something (umbrella term for extrinsic regulation and identified regulation)
Competence	A task lying within the range of a person's capabilities, one of the basic psychological needs
Eduscrum	Adapted version of Scrum for education
Extrinsic regulation	State of being externally moved to do something
Identified regulation	State of being somewhat internally moved to do something
Intrinsic motivation	State of being internally moved to do something
Introjected regulation	State of being somewhat externally moved to do something
Relatedness	An emotional connection with others, one of the basic psychological needs
Relative Autonomy Index	Measure of the extent to which motivation is autonomous
Scrum	Agile software development methodology

Introduction

Motivation is a crucial part of education, as it can be considered the driving force behind “a variety of important learning consequences such as persistence, retention, achievement and course satisfaction” (Chen & Jang, 2010). A common problem in secondary education, however, is the lack of such motivation in students, especially regarding STEM subjects (Science, Technology, Engineering and Mathematics). For example, Dutch students are reported to exhibit low participation in optional STEM courses (van Langen & Dekkers, 2005). Moreover internationally, the interest in following STEM courses has declined due to several reasons, such as the stereotyping of STEM subjects as inaccessible and difficult (van Langen & Dekkers, 2005), an inadequate knowledge of STEM occupations by parents and teachers (Honey, Pearson, & Schweingruber, 2014), a lack of personal interest and the potential earning degree (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011), which decreases students’ sense of competence and thereby their motivation. Autonomous motivation is worth striving for, because it is related to a host of beneficial consequences: more commitment, increased productivity, higher quality results and deeper enjoyment (Ryan & Deci, 2017).

With the self-determination theory, Ryan and Deci demonstrated that support of the basic psychological needs (autonomy, competence and relatedness) leads to intrinsic motivation (Ryan & Deci, 2000). The study investigated different ways of improving motivation, such as Inquiry-Based Learning (IBL) (Capps & Crawford, 2013), the impact of teaching strategies (Bomia et al., 1997) and the consequences of providing for the students’ psychological needs on their intrinsic motivation for science in particular (Peciuliauskiene, 2019). In 1993 common Scrum – an agile project management methodology – was introduced in a software business context as a tool for increasing motivation (Deemer, Benefield, Larman, & Vodde, 2010). In the Netherlands, common Scrum has since been adapted by Willy Wijnands to a version suitable for secondary education, known as Eduscrum (Filho & Lima, 2018). Despite these developments, little research has been done into the use of Eduscrum.

One of the few studies of Eduscrum focuses on the self-regulation of Technasium students, who attend technical courses additionally to their school program (Bongaerts, 2018). In common education, students mainly receive direct instruction from the teacher, but Eduscrum connects students in teams and provides these teams with autonomy, which could increase their sense of relatedness and enables teams to divide the tasks among the team members who are most familiar with a certain task, which may increase their sense of competence. A detailed description of Eduscrum is given in appendix 6. This makes Eduscrum a promising intervention strategy to support the students’ basic psychological needs.

The extent to which basic principles of Eduscrum could be used to foster students’ autonomous motivation for STEM subjects is still unknown, especially regarding a partly online teaching environment. This study aims to find whether there is a connection between online Eduscrum in particular and the autonomous motivation of secondary school chemistry students, which leads to the following research question:

In what ways can basic principles of Eduscrum foster secondary school students’ autonomous motivation for chemistry in a semi-online environment?

This design study uses a mixed-methods approach to account for both quantitative and qualitative data. The qualitative data will be gathered through interviews with focus groups and the quantitative data collection takes place by means of pre- and post-questionnaires. Three sub-questions provide for an answer to the research question:

1. *To what extent does Eduscrum foster secondary school students' autonomous motivation for chemistry?*
2. *Which mechanisms related to motivation do the students report regarding the Eduscrum learning process?*
3. *Which parts of the design do the students report as effective in increasing autonomous motivation and decreasing controlled regulation for chemistry?*

The first sub-question is a quantitative question to determine to what extent Eduscrum fosters students' autonomous motivation. Eduscrum is hypothesized to make a significant improvement in the Relative Autonomy Index (RAI), a measure of the relative position within the motivational spectrum (Peeters, n.d.). The second sub-question focusses qualitatively on the mechanisms that manifest during the Eduscrum intervention. The last sub-question qualitatively inquires which parts of the design are most effective according to the students. It is expected that the support of the basic psychological needs will be responsible for a significant difference in the RAI.

Due to the social distancing measures in the COVID-19 pandemic many schools have been (partly) closed and shifted to hybrid- or distance-learning in an attempt to stop the spread of the Corona-virus (Golberstein, Wen, & Miller, 2020). Secondary school students are at an age in which peer relationships are becoming increasingly important (Oosterhoff, Palmer, Wilson, & Shook, 2020). Therefore, this current situation is a serious threat to students' socio-emotional wellbeing (Urbina-Garcia, 2019) and their sense of relatedness. This underscores the relevance of supporting the basic psychological needs by means of teaching techniques like Eduscrum.

Theoretical Background

Motivational spectrum

Defining one of the key concepts of this study, Reeve states that "motivation refers to any force that energizes and directs behaviour" (Reeve, 2012). This study uses a narrower definition of motivation based on Ryan and Deci's Self-Determination Theory (SDT). The SDT differentiates between internal and external Perceived Locus of Causality (PLOC); autonomous motivation and controlled regulation (Ryan & Deci, 2000). In traditional education controlled motivation is more dominant due to a controlling context, such as a mainly one-size-fits-all approach and grading systems. However, it has been found that those extrinsic measures have a negative impact on the learning process, where autonomous motivation causes a range of positive effects, like better performance and overall well-being (Cerasoli & Ford, 2014; De Brabander & Martens, 2014).

At the origin of the SDT lies the Basic Needs Theory, as both provide insight into the events that induce certain types of motivation. Support of the basic psychological needs of competence, autonomy and relatedness (CAR) likely leads to more autonomous motivation (Ryan & Deci, 2017). Competence refers to a task lying within the range of a person's capabilities (De Brabander & Martens, 2014). Autonomy is related to a person's opportunity to decide for itself and relatedness has to do with an emotional connection between people (Reeve, 2012).

The different types of motivation are not strictly separated, but can be represented in a continuum of motivations (figure 1) which ranges from amotivation (complete lack of motivation) to intrinsic motivation (state of being internally moved to do something) (Ryan & Deci, 2000). Controlled regulation is an umbrella term for the external and introjected regulation, the External Perceived Locus of Causality (E-PLOC). Identified regulation, integrated regulation and intrinsic motivation are summarized with the term autonomous motivation, the Internal Perceived Locus of Causality (I-PLOC).

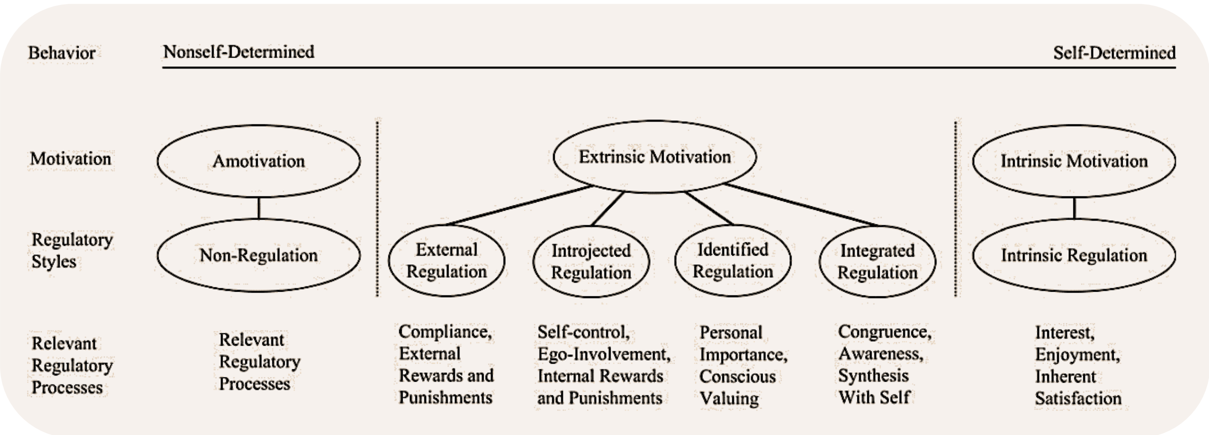

Figure 1: Continuum of Self-Determination Theory (Source: Ryan & Deci, 2000; p.72)

Support of CAR

Following the SDT-framework, autonomous motivation would likely manifest when the basic needs are supported (Chen & Jang, 2010). Internalization is likely to occur in a CAR-supportive environment, meaning that the motivation shifts from controlled regulation to a more autonomous type of motivation.

In order to measure the relative position within the motivational spectrum, the Relative Autonomy Index (RAI) was introduced (Ryan & Deci, 2000). The RAI integrates four constructs in the motivation continuum into one number that can be envisaged to represent a measure for the level of autonomy in the motivation. The four constructs are: external regulation, introjected regulation, identified regulation and intrinsic motivation as given in figure 2. The RAI is determined by the following formula (Peeters, n.d.):

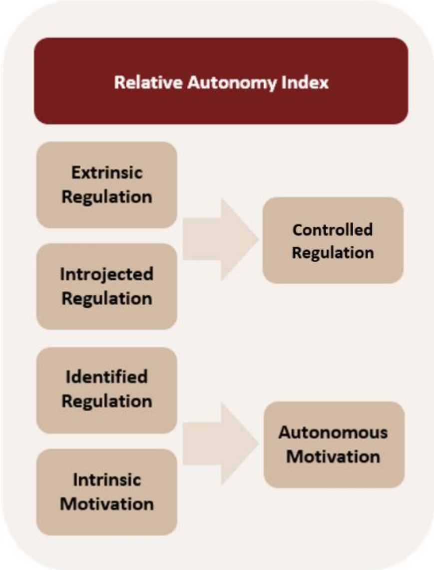

Figure 2: Subscales of SRQ-A

$$RAI = 2 \times Intrinsic + Identified - Introjected - 2 \times External$$

This clarifies the Perceived Locus of Causality (PLOC) with its four subscales of regulation and motivation: external, introjected, identified, and intrinsic (Ryan & Connell, 1989).

Eduscrum and CAR

Eduscrum was developed in order to support the students' basic psychological needs and foster their autonomous motivation. The Eduscrum Cycle resembles the common Scrum process, but it was adapted to an educational setting – also known as Scrum@School (Bongaerts, 2018) – by Willy Wijnands (Filho & Lima, 2018). The common Scrum process belongs to a family of agile project management methodologies, of which Scrum is the most popular method (Deemer et al., 2010). Those agile methodologies were introduced in software development in order to find a more effective way for cooperating. The agile philosophy is marked by 4 characteristics (May, York, & Lending, 2016):

1. "Individuals and interactions over processes and tools;
2. Working software over comprehensive documentation;
3. Customer collaboration over contract negotiation;
4. Responding to change over following a plan."

Scrum empowers teams to work more effectively (Carvalho, Fernandes, Lima, & Mesquita, 2018) and more transparently (Deemer et al., 2010), because it is based on the empirical process control theory which values learning through experience over fixed plans (May et al., 2016).

As it applies these characteristics and methodologies to an educational setting, Eduscrum is a promising intervention for fostering students' autonomous motivation for chemistry, because it provides teams of students with autonomy, connects students in teams and thereby increases their sense of relatedness. In addition to that, it enables teams to divide the tasks among the team members who are most familiar with a certain task, which could increase their sense of competence.

Guiding Frame

The components of Eduscrum suggest a connection with the support of the basic psychological needs. However, only little is known about the effects of Eduscrum on education, so this research will use a bottom-up approach via a guiding frame based on literature. The guiding frame (figure 3) summarizes the potential connection between design principles and the support of the basic psychological needs.

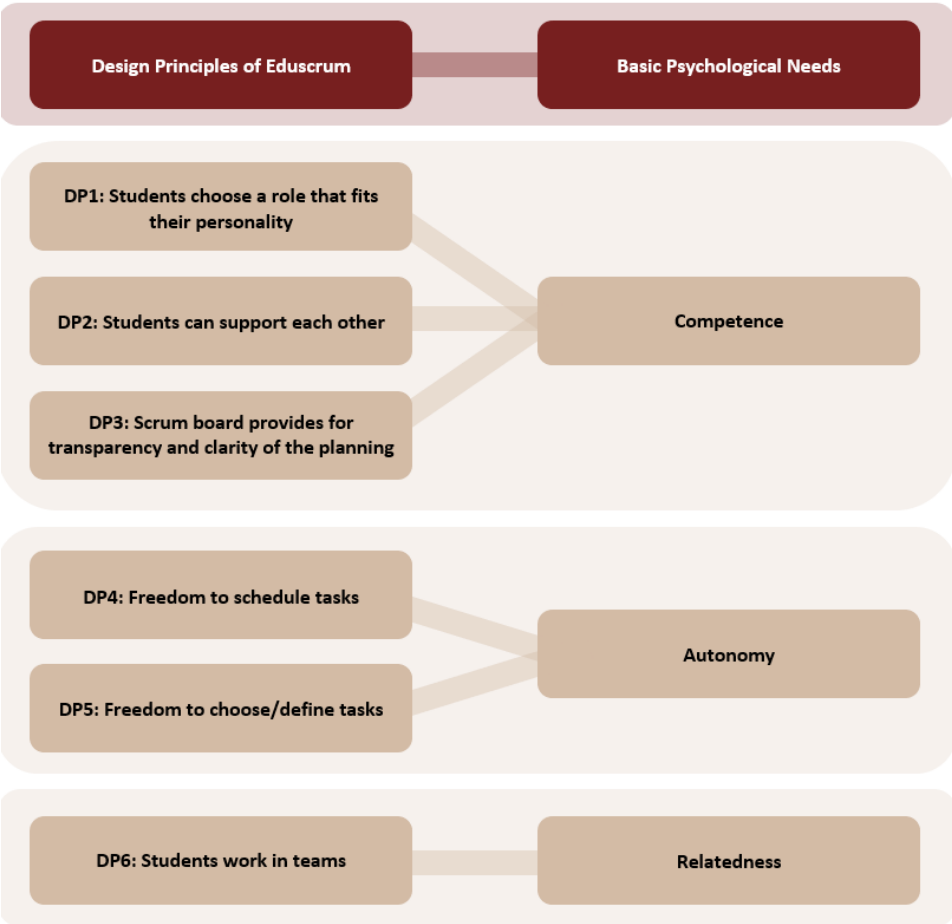

Figure 3: Guiding Frame Eduscrum and Basic Psychological Needs

The guiding frame in figure 3 is based on the high-level conjecture map of Eduscrum for secondary chemistry education (figure 4). The high-level conjecture map hypothesizes answers to the research problems and it suggests ways to test these hypotheses (Wozniak, 2015). Wozniak states that "educational design research (EDR) blends design, research and practice concurrently. It is a long-term approach, wherein practitioners and researchers collaborate to design a solution to a complex educational problem, which is evaluated through multiple iteration of implementations" (Wozniak, 2015). The high-level conjecture map (figure 4) models the embodiments that are expected to lead to the intended outcomes via mediating processes (Bakker, 2019). The design and theoretical conjectures serve as an 'if…, then…' statement that connects the embodiments, mediating processes and outcomes (Sandoval, 2014; Wozniak, 2015). Figure 4 shows the conjecture map of Eduscrum's basic principles for secondary chemistry education including the design elements (embodiments) that were part of the design. The embodiments refer back to the design principles given in figure 3 (p.12). The design conjectures indicate the mediating processes of CAR support, which in turn are promising to increase the Relative Autonomy Index via theoretical conjectures as described in the Theoretical Framework.

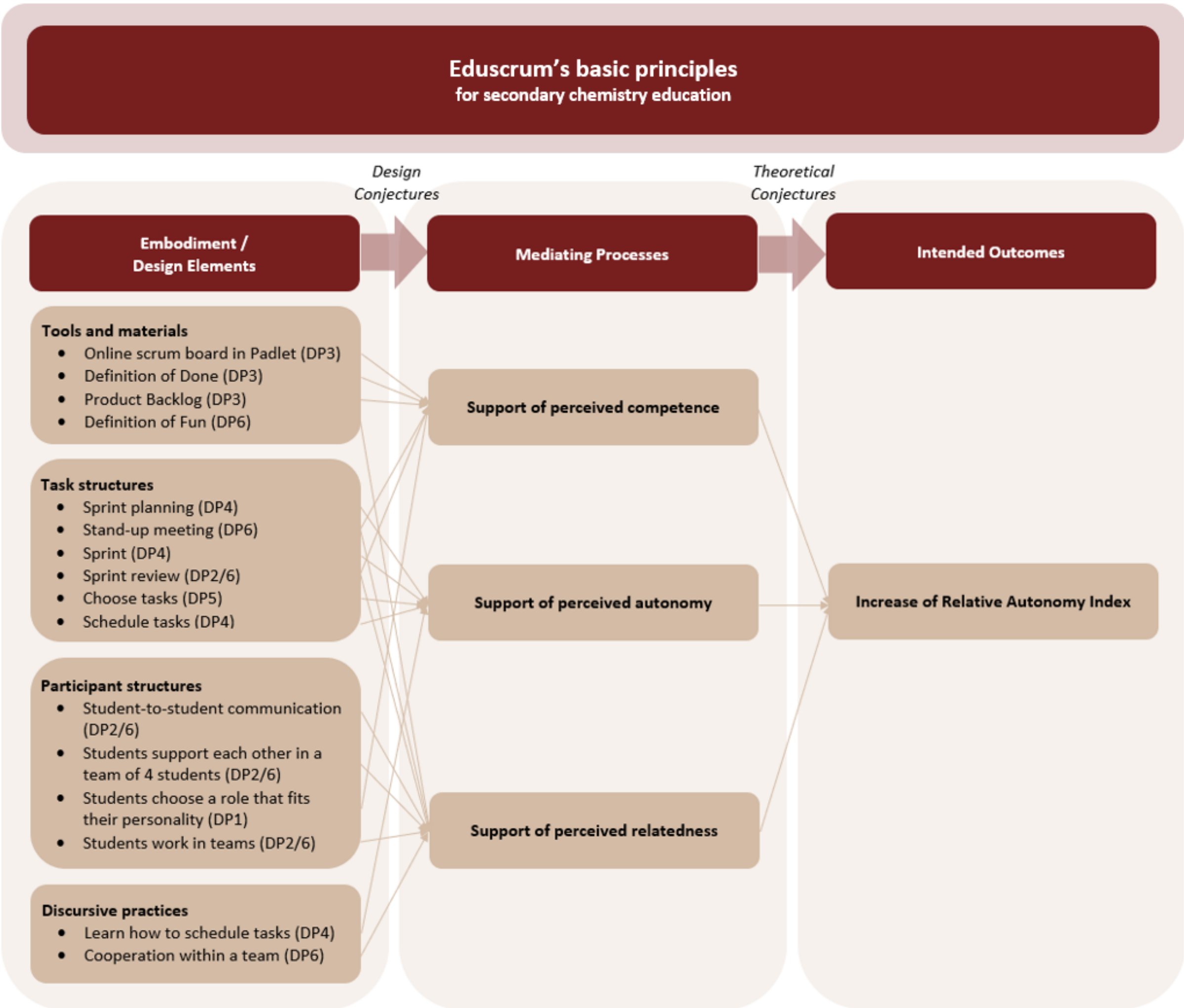

Figure 4: Conjecture map of Eduscrum for secondary chemistry education

Three properties of Eduscrum will likely increase the students' sense of competence. The first is the possibility of choosing a role that fits the students' personality. Teams are made based on the students' qualities, ensuring that the team members receive tasks that match their own qualities. In addition to that, other teammates are very approachable, which makes it easier for students to ask for support. This in turn can increases their competence level. The scrum board contributes to competence too, because the schematic representation on a scrum board is transparent and clear. This gives the students insight in the process of scheduling and planning. When their competence level is higher, the autonomous motivation is likely to increase too (Ryan & Deci, 2000).

Students can act relatively autonomously during the process of Eduscrum, which will foster their autonomous motivation because they have freedom to define and/or choose suitable learning tasks and to schedule them (Ryan & Deci, 2000). Research has shown that a noncontrolling environment leads to deeper rote learning, greater interest and better conceptual learning (Grolnick & Ryan, 1987).[1] The students will not receive traditional homework, but instead they define their own homework and school tasks. They are even allowed to decide for themselves when they will carry out their tasks (within the boundaries set by their teacher).

Finally, students' sense of relatedness is likely to increase by the Eduscrum cycle, because the students work in teams.[2] This supported relatedness will foster students' autonomous motivation for chemistry. This key element of Eduscrum forms the basis of the learning process in this cycle, because it introduces opportunities for increasing the sense of competence mentioned above. In the educational practice, daily Scrum meetings are not possible, due to the other courses and subjects that students attend, so those stand-ups should be organized regularly during the lessons (Persson, Kruzela, Allder, Johansson, & Johansson, 2012). It can be useful to use short sprints (periods of working on a set of tasks) to ensure the interaction between students and teacher (Persson et al., 2012).

[1] Although Grolnick and Ryan did not apply their study to 9th grade students, their conclusions are likely generalizable, because support of autonomy is one of the basic psychological needs of every human being.

[2] Due to the Corona-crises many schools are closed and switched to online education (Golberstein et al., 2020), which is a serious threat to their wellbeing (Urbina-Garcia, 2019) and threatens the team work. Intrinsic motivation is found to be initially higher for students following an online course than students following face-to-face education. Online education requires different student skills than face-to-face education. A high degree of self-regulation is demanded, especially when online courses progress, which leads to a high degree of drop-outs (Barak, Watted, & Haick, 2016). Contrary to the aforementioned, students are found more motivated to finish a course when they are engaged in active co-learning with peers (Barak et al., 2016), which is promising for the Eduscrum team approach, even in an online environment.

Methodology

Outline of the study

The study as outlined in figure 5 was conducted during a period of half a year, with the exception of the first design and the informal pilot that were conducted beforehand. The study started with a pilot of 5 lessons (2,5 weeks) in June and July of 2020 with 94 grade 9 students in two classes of a Dutch secondary school. Grade 9 corresponds to the third year of Dutch secondary education in which students are 14-15 years old. The pilot was evaluated via informal open ended interviews with small focus groups with 2 students of every class (8 students in total). The data were gathered informally by notes of the researcher and were divided in positive and negative experiences with the design as they were reported by the students. The design was adapted based on the input from the focus groups in the evaluation of the pilot, leading to a first high-level conjecture map as given in figure 4 (p.13).

After the redesign, the study entered an iterative cycle, starting with a prequestionnaire, followed by a 3-4 week iteration in September and October of 2020 with a post-questionnaire at the end of the iteration. Focus group interviews (16 randomly selected students in total) ended the first iteration and lead to a redesign after which the same cycle started for the second iteration in November and December of 2020. The second iteration also included a control group for a more in-depth study whether a difference in the RAI could be visible with respect to the control group.

A mixed methods approach was adopted, because the research question contains a quantitative part (whether the students' autonomous motivation for chemistry was fostered, sub-question 1) as well as a qualitative part (in what ways the autonomous motivation was fostered, sub-question 2 and 3).

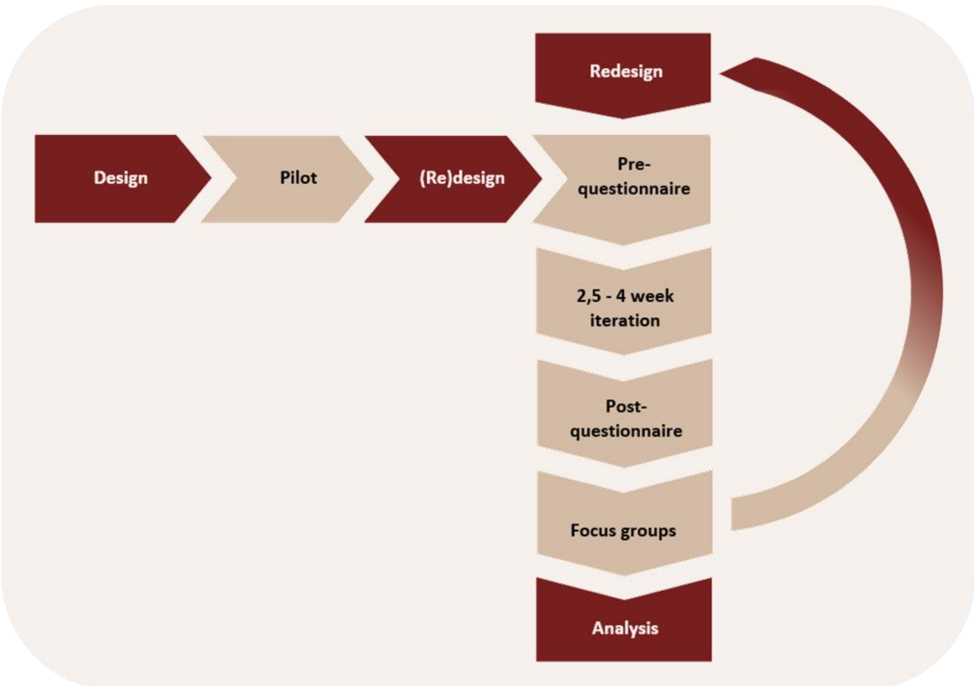

Figure 5: Schematic representation of the study

Sub-question 1: Quantitative

Sub-question 1: To what extent does Eduscrum foster secondary school students' autonomous motivation for chemistry?

The quantitative part of this study consists of questionnaires and a pre- and post-test for both iterations. During the first iteration no control group is used, because of the explorative character of the first iteration, since it serves solely to check whether there is a significant effect in the Relative Autonomy Index (RAI). The first iteration of 3 weeks is evaluated by semi-structured interviews with focus groups. Each of the target classes is represented by 4 randomly selected students in the focus group interviews (table 6, p.24). Information is distracted from the evaluation with the students to further improve the design and the conjecture map.

During the second iteration a control group is added in order to investigate whether there is a significant effect in the RAI of the intervention with respect to the pre-test and relative to the control group. The interviews with student focus groups during 2 iterations of 3-4 weeks account for the qualitative part of the study. The students in the target group during the first iteration receive the role of control group during the second iteration.

An example of the scrum board from the design that was based on the conjecture map and used for iteration 1 is given in figure 6 to illustrate the design. A detailed description of Eduscrum in practice is given in appendix 6.

Figure 6: Example of scrum board from the design (iteration 2)

Quantitative Data Analysis

The results of the Self-Regulation Questionnaire Academic (SRQ-A) are used to determine the RAI of the students. The RAI of the post-test is compared to the RAI of the students before the intervention to determine whether a significant change can be detected. During the second iteration this RAI is also compared to the RAI of the control group to investigate whether a significant difference can be seen. The quantitative data of the pre-, interim and post-questionnaires are analysed in SPSS Statistics via a paired samples t-test (first iteration) and additionally an ANOVA (second iteration). The results of the SPSS analysis are used to check whether the hypothesis for the first sub-question was correct. That hypothesis stated that Eduscrum would indeed foster secondary school students' motivation for chemistry, visible by a significant difference in the RAI of the pre- and post-questionnaires.

Quantitative instruments

The means for each of the constructs of the SRQ-A and the RAI, as well as the gain, are given in table 8-10 (p.27-28). A significant gain in the Relative Autonomy Index would indicate an increase in autonomous motivation. From the RAI-formula (p.11) it follows that a significant decrease in the controlled regulation constructs (extrinsic and introjected) and a significant increase in the autonomous motivation constructs (identified regulation and intrinsic motivation) would lead to such a gain in the RAI. The gain is calculated by the following formula:

$$Gain = Mean_{post\text{-}test} - Mean_{pre\text{-}test}$$

Reliability

The reliability of the SRQ-A questionnaire was investigated by calculating Cronbach's alpha using all participant data for the four subscales (as represented in Figure 2, p. 11) that are part of the SRQ-A:

- Extrinsic Regulation
- Introjected Regulation
- Identified Regulation
- Intrinsic Motivation

The results of the Cronbach's alpha analysis are represented in Table 1, where scales with an α > 0.7 are commonly considered reliable for science education research (Taber, 2018). Following this rule, the values of the Introjected Regulation, Identified Regulation and Intrinsic Motivation are acceptable. The Cronbach's alpha value of Extrinsic Regulation is slightly lower than 0.7, but it is still considered reasonable and can be useful for further investigation (Taber, 2018). No specific question of the SRQ-A could be identified to be responsible for this relatively low value of alpha. With this limitation in mind, all subscales of the SRQ-A are used to calculate the RAI.

Table 1: Reliability Analysis of SRQ-A subscales

Subscale	Cronbach's Alpha
Extrinsic Regulation	0.666
Introjected Regulation	0.845
Identified Regulation	0.822
Intrinsic Motivation	0.863

Normality for t-test

The quantitative data of iteration 1 and 2 are analysed via a t-test, which requires a set of assumptions to be met. For the t-test the dependent variable should be measured on a continuous scale and the independent variable should consist of two categorical, related groups. Both assumptions were met. The distribution of differences in the dependent variable should be approximately normally distributed and no significant outliers should be visible. This was investigated via a Shapiro-Wilk test, which yielded significant results for most constructs (table 2, p. 20), indicating significant deviations from normality ($p > 0.05$). Due to the relatively small sample size some deviations from normality are quite common. Furthermore, a t-test is known to be quite robust for non-normality and was therefore employed notwithstanding (Box, 1953). There were no significant outliers, which is visible in the Q-Q plots of the RAI for the pre- and post-test of iteration 1 and 2 (figure 7 and 8). The full set of Q-Q-plots for the t-tests is given in appendix 4.

Table 2: Normality Analysis for t-tests via Shapiro-Wilk test

Construct	Iteration 1		Iteration 2	
	Pre-test significance	Post-test significance	Pre-test significance	Post-test significance
Extrinsic Regulation	0.242	0.317	0.006	0.000
Introjected Regulation	0.258	0.003	0.232	0.221
Identified Regulation	0.219	0.004	0.022	0.384
Intrinsic Motivation	0.018	0.388	0.071	0.296
Relative Autonomy Index	0.325	0.126	0.093	0.801

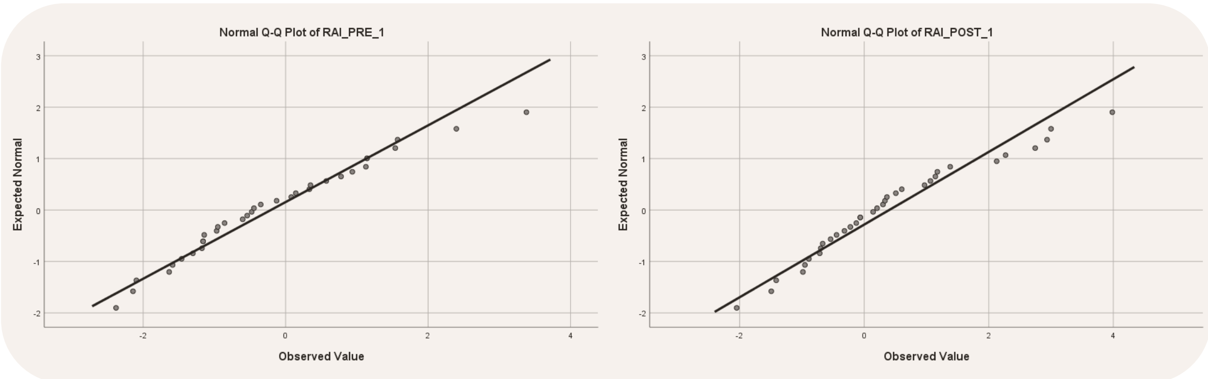

Figure 7: Q-Q plots of RAI of iteration 1 for t-test

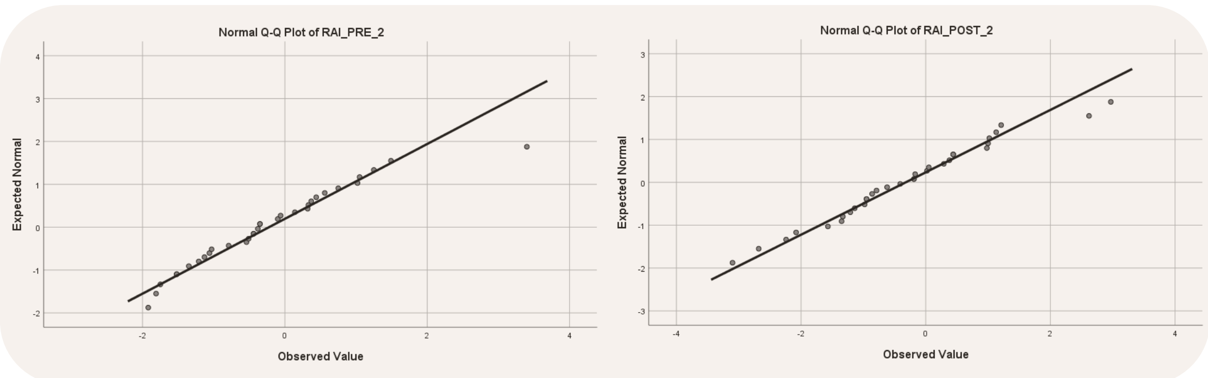

Figure 8: Q-Q plots of RAI of iteration 2 for t-test

Normality for ANOVA

The quantitative data of iteration 2, which included an experimental group and a control group, are analysed in SPSS via an ANOVA, which requires a set of assumptions to be met. For the ANOVA the dependent variable (the RAI values) should be measured on a continuous scale and the independent variable should consist of two or more categorical, independent groups, in this case the target group and the control group. In addition to that, there should be independence of observations. All the previously mentioned assumptions were met. The distribution of differences should be approximately normally distributed for each category of the independent variables and no significant outliers should be visible. This was investigated via a Shapiro-Wilk test, which yielded significant results for most constructs (table 3), indicating significant deviations from normality ($p > 0.05$). Due to the relatively small sample size some deviations from normality are quite common. Furthermore, an ANOVA is known to be quite robust for non-normality and deviations from normality were therefore employed notwithstanding (Box, 1953). There were no significant outliers, which is visible in the following Q-Q plots of the RAI for the pre- and post-test of iteration 2 (figure 9). The full set of Q-Q-plots for the t-tests is given in appendix 4.

Table 3: Normality Analysis for ANOVA via Shapiro-Wilk test

Construct	Iteration 2 Pre-test significance	Iteration 2 Post-test significance
Extrinsic Regulation	0.002	0.000
Introjected Regulation	0.076	0.026
Identified Regulation	0.003	0.308
Intrinsic Motivation	0.092	0.368
Relative Autonomy Index	0.382	0.865

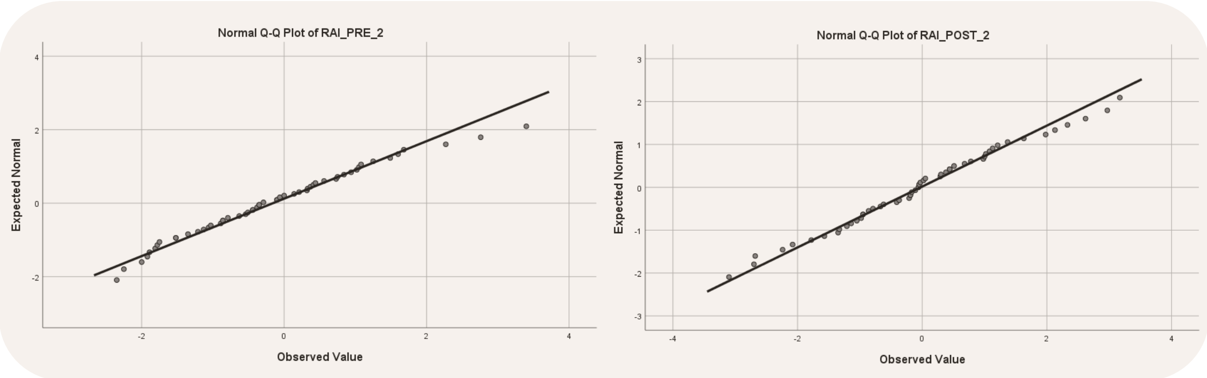

Figure 9: Q-Q plots of RAI of iteration 2 for ANOVA

Finally, there needs to be homogeneity of variances. This assumption is tested in SPSS Statistics using Levene's test for homogeneity of variances. Levene's test showed that all constructs were roughly equal, except for the Introjected Regulation of the pre-test which showed a significance < 0.05 (table 4).

Table 4: Levene's test for homogeneity ANOVA iteration 2

Construct	Pre-test F(1,52)		Post-test F(1,52)	
	Levene's statistic*	Significance*	Levene's statistic*	Significance*
Extrinsic Regulation	0.022	0.884	0.420	0.520
Introjected Regulation	7.070	0.010	1.158	0.287
Identified Regulation	0.101	0.752	0.309	0.581
Intrinsic Motivation	0.658	0.421	0.100	0.753
Relative Autonomy Index	2.338	0.132	0.003	0.954

* Based on mean

Sub-questions 2 and 3: Qualitative

Sub-question 2: Which mechanisms related to motivation do the students report regarding the Eduscrum learning process?

Sub-question 3: Which parts of the design do the students report as effective in increasing autonomous motivation and decreasing controlled regulation for chemistry?

Sub-questions 2 and 3 are answered by a qualitative method (semi-structured interviews), because the interest lies in the nature of the reasons that students report. Furthermore, since no full model for the mediating processes is available, qualitative data can give access to mechanisms that may be missed by a purely quantitative approach (Denscombe, 2010).

Qualitative Data Analysis

The qualitative data for sub-questions 2 and 3 were gathered by means of semi-structured interviews with focus groups. The focus groups were formed by randomly selecting 4 students out of every target class. The semi-structured interviews with the focus groups were recorded, transcribed, anonymized and coded via the coding scheme in table 5 (p.23), which yielded a total of 193 segments. 60 of these segments (31%) were coded by a second coder, which resulted in 59 agreements and a Cohen's kappa of 0.980, which is considered a high interrater reliability.

Qualitative instruments

The interview scheme is represented in Appendix 2 and was designed to stay close to the guiding frame (figure 3, p.12) and mediating processes of the conjecture map (figure 4, p.13). Therefore, the questions were explicitly focused on the perceived support of the basic psychological needs of competence, autonomy and relatedness. Topics that were discussed within the focus groups are the impact of the student cooperation within the Eduscrum teams, the perceived autonomy of the students, the sense of competence of the students and how the design could be improved (Appendix 2).

In order to determine the mechanisms that occur during the Eduscrum process, the answers of the students in the interviews were coded top down following the categories dictated by the Self Determination Theory (SDT) and Basic Needs Theory (Competence, Autonomy, Relatedness) combined with + or – (positive and negative remark). One bottom-up category was added: T* (tips/ recommendations), for responses that give suggestions for improvements. The coding rubric is summarized in table 5 and fully attached in Appendix 3, which also includes the following examples of quotes belonging to each coding category:

C+: *“You can just help each other et cetera and that is very helpful and after that you have, after that, if that doesn't work, then you still have the teacher, so I really liked that.”*

C-: *“Well, it looks a little complicated and so on. And then yes, you had explained it, but yes, then you have to start it yourself at home. And then you actually don't know anymore.”*

A+: *"And it is also nice that you can decide for yourself when you actually do something, as long as you just always do it."*

A-: *"Yes then it didn't really feel like you were planning yourself..."*

R+: *“I thought it was fun [sociable], that's an advantage.”*

R-: *“Yeah, but I don't know, he just didn't and he just didn't interfere, he just did what he was going to do himself and otherwise he didn't really interfere with the group.”*

T*: *“Yes, uh, I think, but I just like that better, just that [column] ‘doing’, that can really be removed for me, because that is so much work to drag all those things. It took us really ten minutes to just drag those things, or something like that, that's a bit of a waste of your time.”*

Table 5: Coding Scheme Summary

Construct	Relationship	Description	Code
Competence	Positive Negative	Perceived support of competence	C+ C-
Autonomy	Positive Negative	Perceived support of autonomy	A+ A-
Relatedness	Positive Negative	Perceived support of relatedness	R+ R-
Recommendations	-	Recommendations for redesign	T*

Context and participants

The design research is executed in 9th grade Dutch secondary chemistry education in 2 classes: Havo 3 (Senior General Secondary Education) and VWO 3 (Pre-University Education). The students have only had an introductory course in general science as a preparation for their third year of secondary school in which they attend a new mandatory chemistry course for the duration of a school year. Other classes participated in the informal pilot in June and July of 2020 than in iteration 1 and 2 in September and October of 2020, due to the informal character of the pilot. Focus group interviews were conducted with a total of 8 randomly selected students per iteration. Detailed information about the participants is represented in table 6.

50 students (9th grade) participated in the first iteration (table 6), of whom 34 students completed both the pre-test and post-test. During the second iteration 58 students (9th grade) participated in the target group, and the 50 students from the first iteration participated as a control group during the second iteration (table 6). 32 students out of the target group answered both the pre-test and post-test and 22 students of the control group filled out both tests.

Table 6: Participant information in chronological order of data collection

Part of study	Role	Number of classes	Type of classes	Number of students	Topic
Pilot	Pilot group	2	Havo 3	49	A classification of substances (metal, salt, molecular substance)
		2	VWO 3	45	
Iteration 1	Target group	1	Havo 3	27	Methods of separation (separating mixture to pure substance)
		1	VWO 3	23	
Iteration 2	Target group	1	Havo 3	28	Building blocks of substances (atoms forming elements and compounds)
		1	VWO 3	30	
	Control group	1	Havo 3	27	
		1	VWO 3	23	

COVID-19 implications

Iteration 1

Due to the social distancing measures in the COVID-19 pandemic many schools have been (partly) closed and shifted to hybrid- or distance-learning in order to stop the spread of the Corona-virus (Golberstein et al., 2020). During the first iteration the students were taught on location, except for quarantined students, who learned through hybrid learning. An online Scrum board was designed using the software Padlet, in order to make it accessible for students at school as well as students in quarantine. The stand-up meetings were regularly organized in class during iteration 1 and the teams were able to collaborate in class. The focus group interviews of the first iteration were also on location.

Iteration 2

Halfway through the second iteration, education shifted to distance-learning due to the COVID-19 restrictions (lockdown) at that time. Stand-up meetings were organized via break-out rooms in Zoom and focus group interviews were organized via Zoom (an online audio and video conferencing platform). Therefore, the interviews of the second iteration could not be conducted satisfactorily.

The interview data of iteration 2 were only audiotaped and not further analysed, because iteration 2 was considered not valid due to the major changes during the iteration because of the government-implemented COVID-19 restrictions that were proclaimed during the second iteration (detailed discussion on p.35). Due to the COVID-19 restrictions, the pre-test was taken during education on location, whereas the post-test was taken under lockdown circumstances. Besides that, the absence rates (24%) during iteration 2 were much higher than during iteration 1 (10%), due to quarantine cases of COVID-19.

Results

Results of Pilot

The results of the interviews during the informal pilot are given in Table 7. The comments made by the students were connected to CAR and divided between positive and negative experiences.

Table 7: Reported experiences with the design during the pilot

Positive experiences	CAR subscale	Negative experiences	CAR subscale
• Online scrum board • More motivated for chemistry because of transparency about tasks and progress • Clear and structured scrum board • Useful star classification • Threshold-lowering for asking for help	C	• Technical issues • Long lists on scrum board • Less instruction by teacher than during 'normal' lessons • Star classification time-consuming • Much to do at the same time	C
• Freedom to schedule tasks • Optional tasks	A	• Too much freedom. Deadline halfway the iteration would be useful.	A
• Pressure not to be the last person of the team to finish tasks • Collaboration within a team • Sociable setting (enjoyable)	R	• When 1 person is not very involved, the other team members experience negative effects	R

Quantitative Results

Sub-question 1: To what extent does Eduscrum foster secondary school students' autonomous motivation for chemistry?

Average scores iteration 1

Table 8 and figure 10 show the scores of iteration 1 for each of the constructs on a 5-point Likert scale ranging from strongly disagree to strongly agree. The standard deviation is included in the table and figure.

Table 8: Averages of all subscales of the pre- and post-test for the target groups of iteration 1

	Iteration 1 (n=34)				
Subscale	**Pre-test**	**Standard Deviation**	**Post-test**	**Standard Deviation**	**Gain**
Extrinsic Regulation	2.402	0.383	2.284	0.361	-0.118
Introjected Regulation	1.631	0.383	1.539	0.446	-0.092
Identified Regulation	2.899	0.583	2.803	0.508	-0.097
Intrinsic Motivation	1.664	0.414	1.853	0.528	0.189
Relative Autonomy Index	-0.208	1.341	0.401	1.416	0.608

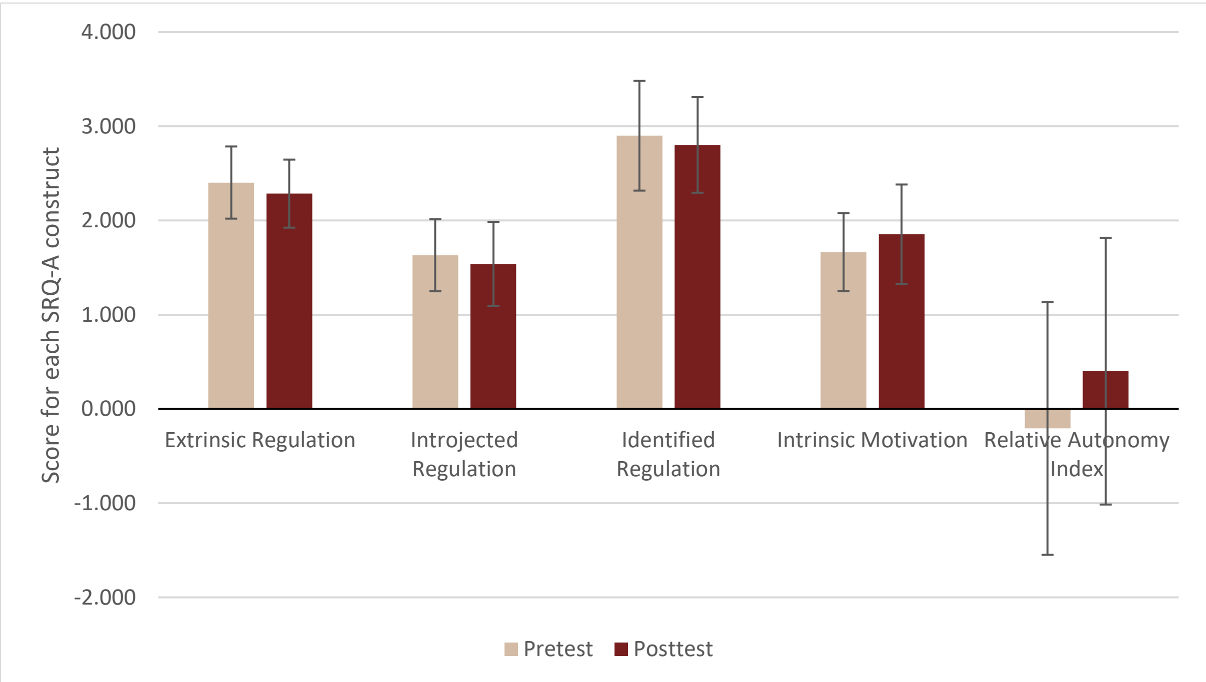

Figure 10: Average scores of all subscales for the target groups of iteration 1

Average scores iteration 2

Table 9 (target groups) and table 10 (control groups) show the scores of iteration 2 for each of the constructs on a 5-point Likert scale ranging from strongly disagree to strongly agree. The standard deviation is included in the tables.

Table 9: Averages of all subscales of the pre- and post-test for the target groups of iteration 2

	Iteration 2 (n=32)				
Subscale	Pre-test	Standard Deviation	Post-test	Standard Deviation	Gain
Extrinsic Regulation	2.528	0.347	2.546	0.323	0.018
Introjected Regulation	2.113	0.377	2.034	0.343	-0.080
Identified Regulation	2.911	0.934	2.822	0.503	-0.089
Intrinsic Motivation	2.018	0.519	1.991	0.533	-0.027
Relative Autonomy Index	-0.223	1.146	-0.321	1.374	-0.098

Table 10: Averages of all subscales of the pre- and post-test for the control groups of iteration 2

	Iteration 2 (n=22)				
Subscale	Pre-test	Standard Deviation	Post-test	Standard Deviation	Gain
Extrinsic Regulation	2.520	0.363	2.434	0.264	-0.086
Introjected Regulation	1.741	0.567	1.728	0.377	-0.136
Identified Regulation	2.994	0.433	2.987	0.406	-0.007
Intrinsic Motivation	1.863	0.563	2.006	0.452	0.143
Relative Autonomy Index	-0.063	1.474	0.403	1.375	0.466

Figure 11 represents the results of the pre- and post-test of iteration 2 for the target groups and control groups. The standard deviation is included in the figure.

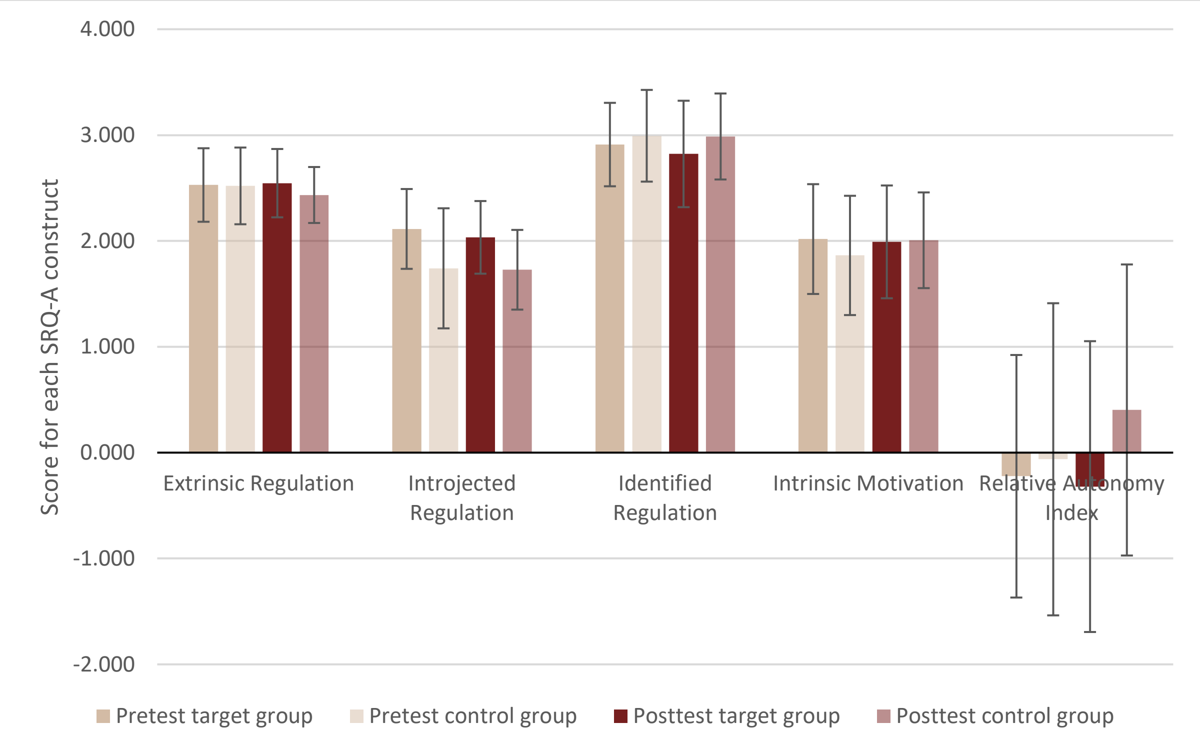

Figure 11: Average scores of all subscales for the target and control groups of iteration 2

T-test iteration 1

Table 11 represents the t-test analysis for iteration 1. Three of the constructs – Introjected Regulation, Intrinsic Motivation and the RAI – showed a significant difference between the pre-test and post-test. t(33) = -2.671, p = 0.012. There is a statistically significant increase in the RAI from -0.208 ± 1.341 to 0.401 ± 1.416 (p = 0.012); an improvement of 0.608 ± 1.328.

Table 11: Analysis of t-test for iteration 1

Subscale	Mean	Std. Deviation	Std. Error Mean	95% Confidence interval		t	df	p
				Lower	Upper			
Extrinsic Regulation	0.118	0.378	0.065	-0.014	0.250	1,815	33	0.079
Introjected Regulation	0.092	0.257	0.044	0.002	0.181	2,074	33	0.046
Identified Regulation	0.097	0.368	0.063	-0.032	0.225	1,530	33	0.136
Intrinsic Motivation	-0.189	0.473	0.081	-0.354	-0.024	-2,332	33	0.026
Relative Autonomy Index	-0.608	1.328	0.228	-1.072	-0.150	-2,671	33	0.012

T-test iteration 2

Table 12 represents the t-test analysis for iteration 2. None of the five constructs showed a significant difference between the pre-test and post-test. t(31) = 0.590, p = 0.559. There is no statistically significant effect on the RAI from -0.223 ± 1.146 to -0.321 ± 1.374 (p = 0.559).

Table 12: Analysis of t-test for iteration 2

Subscale	Mean	Std. Deviation	Std. Error Mean	95% Confidence interval		t	df	p
				Lower	Upper			
Extrinsic Regulation	-0.018	0.275	0.049	-0.117	0.082	-0.360	31	0.722
Introjected Regulation	0.080	0.354	0.063	-0.048	0.207	1.272	31	0.213
Identified Regulation	0.089	0.359	0.063	-0.041	0.218	1.399	31	0.172
Intrinsic Motivation	0.027	0.401	0.071	-0.118	0.171	0.375	31	0.710
Relative Autonomy Index	0.098	0.934	0.165	-0.239	0.434	0.590	31	0.559

ANOVA iteration 2

There was no statistically significant difference between the RAI of the target groups and the control groups as determined by one-way ANOVA (F(1,52) = 0.202, p = 0.655) for the pre-test and (F (1,52) = 3.617, p = 0.063 for the post-test. Table 13 represents the analysis of the one-way ANOVA for iteration 2.

Table 13: Analysis of ANOVA for iteration 2

Subscale	Pre-test				Post-test			
	Sum of Squares	df	F	p	Sum of Squares	df	F	p
Extrinsic Regulation	6.498	53	0.007	0.932	4.859	53	1.806	0.185
Introjected Regulation	12.965	53	8.410	0.005	7.851	53	9.576	0.003
Identified Regulation	8.848	53	0.533	0.468	11.655	53	1.632	0.207
Intrinsic Motivation	15.318	53	1.080	0.303	13.093	53	0.012	0.914
Relative Autonomy Index	86.680	53	0.202	0.655	105.019	53	3.617	0.063

Qualitative Results

Sub-question 2: Which mechanisms related to motivation do the students report regarding the Eduscrum learning process?

Sub-question 3: Which parts of the design do the students report as effective in increasing autonomous motivation and decreasing controlled regulation for chemistry?

The number of responses belonging to a certain category that were uttered during the semi-structured interviews are given in figure 12. Figure 12 shows that the students reported more negative comments on competence than positive comments. The positive comments on autonomy and relatedness outnumbered the negative comments in these categories. However, the students came up with a list of recommendations for the redesign.

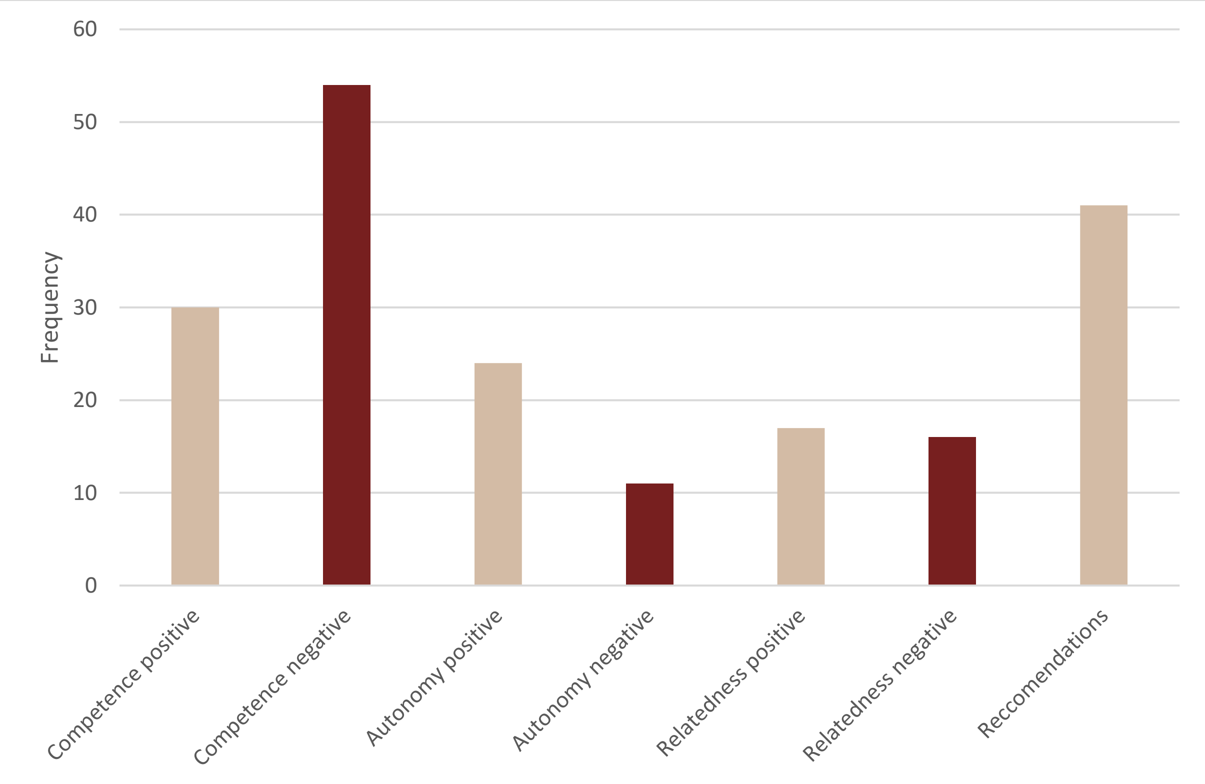

Figure 12: Distribution of interview codes for iteration 1 over the coding categories

Competence

The students reported the design to be unclear and difficult to complete by themselves. Examples of quotes coded as ‘competence -’ are:

> *Student 6: “At first I thought it was very unclear!”*
>
> *Student 1: “Well, it looks a little complicated and so on. And then yes, you had explained it, but yes, then you have to start it yourself at home. And then you actually don't know anymore.”*

The students also mentioned the number of categories on the scrum board and that they missed explanation of the teaching subject by the teacher.

> *Student 3: "There are too many things. To do, those things you have to do, things you are doing, things you have finished."*

> *Student 8: "The disadvantage was the explanation, that you were lagging behind or that it was also much less."*

On the other hand, the students reported that it was clear when they had to do which tasks and they experienced this design easier as the traditional teaching before the design, because in this design they could easily ask for help from students or the teacher. Examples of quotes coded as 'competence +' are:

> *Student 3: "Eh, yeah, well, that was clearly stated when. That was clearly stated."*

> *Student 6: "Yes, it was the case with us, if you did not understand something - or you say well I will postpone it for another week, it really does not work, then it was also the case that we tried to help and understand each other so in that sense, in that sense there was help and yes, when we look at the teacher when there are questions, you can just ask them, so you will also be helped."*

Autonomy
Many comments were made about the freedom the students had to schedule their own tasks. Examples of quotes coded as 'autonomy +' are:

> *Student 5: "It provides for an overview of all the tasks you have to do and then you can decide by yourself what you want to do. I don't know, then you can also decide like, now I don't have time. And then, then you just do it another time or just as homework."*

> *Student 3: "It's just what you do, it's your own decision."*

> *Student 8: "Advantages, I think, are just that you have slightly more freedom..."*

> *Student 5: "You are not constantly monitored indeed."*

The students also mentioned that the elective tasks and the weekly deadlines put extra pressure on them. Examples of quotes coded as 'autonomy -' are:

> *Student 8: "I found it difficult, because you also saw kind of that deadline."*

> *Student 6: "Yes, yes, I just think that you should have done that, that everything should just be finished, but with choice tasks that is not necessary at all, as a kind of voluntarily, but I really had to get used to that."*

Relatedness
The students reported mainly positive comments about the support of relatedness by saying that the Eduscrum approach was fun, because they worked together on their tasks and did not want to disappoint the other team members, but to make them proud of each other. Examples of quotes coded as 'relatedness +' are:

> *Student 7: "I thought it was fun [sociable], that's an advantage."*

> *Student 6: "Yes, you schedule tasks independently, but you do it together too. So you work together but you also work alone. That uh, I liked that about it."*

> *Student 5: "Yeah, so it's better together. I always like that. That's chill or something like that."*

> *Student 7: "I think it is mostly because you work together in this case and you don't want to disappoint the others, […] and at the moment, I really try to stay on track, to make sure the others can be kind of proud of each other."*

On the other hand, the students mentioned that the communication within the team was not as good as they had hoped, because some students just worked individually and did not cooperate with the team. Besides that, they mentioned that some students just had a bad work attitude. Examples of quotes coded as 'relatedness -' are:

> *Student 6: "Eh, yes, it is, what was kind of disappointing for me was that uh, student X went after it, with the question of 'Yes, who finished this?' But not really (…)that you keep an eye on the others to see if he or she succeeds and stuff. I thought that was a pity, so that could be better, if you communicate better with each other.*

> *Student 1: "Yeah, but I don't know, he just didn't and he just didn't interfere, he just did what he was going to do himself and otherwise he didn't really interfere with the group."*

> *Student 3: "There are, of course, people who just, yes, have a bad work attitude."*

Recommendations

A number of recommendations could be distilled from the list of positive and negative comments on the basic psychological needs. Furthermore, the list of utterances on recommendations resulted in a list of improvements for the design, represented per category in table 14.

Table 14: List of recommendations for redesign and implementation

Category	Topic of comments	Count	Implementation in redesign
Simplify/clarify scrum board	Star classification of tasks	5	Delete star classification
	Too extensive scrum board	12	Delete descriptions of assignments Delete column 'doing'
	Schedule explanation	3	Overview of explanation moments
	Unclear scrum board (too complex)	5	Scrum board per week
Demanding design	Many tasks	4	Delete choice tasks
	Pressure of choice tasks	4	Delete choice tasks
	Other	4	-
More explanation	Less explanation by teacher	5	Short plenary explanation every lesson
	Mistakes due to working ahead	3	Other explanation on demand
	Other	5	-
Communication within team	Chat function	5	Chat function per team
	Communication within scrum team	7	Short weekly evaluation per team (sprint review)
	Group assignments	3	Group assignment
	Other	1	-

A few examples of recommendations are listed below. Among the major aspects that the students mentioned were reducing the size of the scrum board, making the design less demanding, offering the students more explanation of the teaching subject and stimulating more communication within the teams (table 13, p.34).

> *Student 4: "So yeah, maybe it would be helpful that you have, let's just say, a planning board [scrum board] per lesson or per week."*
>
> *Student 5: "Oh so, yes, still, yes, those uh, slightly less obligatory tasks or something like that."*
>
> *Student 5: "Or maybe also deal with assignments a bit more in class..."*
>
> *Student 4: "So maybe it would be useful if there is something of a chat, where you can discuss."*

Conclusion

This study aimed to investigate whether the use of basic principles of Eduscrum in a partly online environment could foster secondary students' autonomous motivation for chemistry. It was hypothesized that the students' motivation for chemistry could indeed be fostered by supporting the basic psychological needs, which would become visible in a significant improvement in the Relative Autonomy Index.

1. *To what extent does Eduscrum foster secondary school students' autonomous motivation for chemistry?*

The data of the paired-samples t-test and ANOVA are used to answer the first sub-question. While the first iteration showed a statistically significant increase in the RAI, there was no evidence of a significant increase in the RAI among the data of the second iteration. In addition to that, a one-way ANOVA was conducted to determine whether there was a significant difference between the RAI of the target group and of the control group. The ANOVA shows no statistically significant difference between the groups. The results of the t-test of iteration 1 lead to adoption of the hypothesis for the first sub-question that Eduscrum can indeed foster the students' autonomous motivation for chemistry, as demonstrated by a significant improvement in the RAI. Contrary, the results of the t-test of iteration 2 and the ANOVA show no significant difference in the RAI.

2. *Which mechanisms related to motivation do the students report regarding the Eduscrum learning process?*

The second sub-question is answered by information distilled from the students' responses, who generally reported support of the basic psychological needs of autonomy and relatedness, while competence is mainly reported as being not supported or even thwarted.

3. *Which parts of the design do the students report as effective in increasing autonomous motivation and decreasing controlled regulation for chemistry?*

The students' responses were used to answer the third sub-question. The students explicitly mentioned the student cooperation within the Eduscrum team, their freedom to schedule their own tasks and the overview of a moderate and clear scrum board to be effective in supporting the basic needs.

All in all, the answers to the three sub-questions lead to the overall conclusion to the following research question: '*In what ways can basic principles of Eduscrum foster secondary school students' autonomous motivation for chemistry in a semi-online environment?'* The results of this study show that mainly the team, the freedom to schedule tasks and a moderate, clear scrum board are effective in supporting the basic psychological needs of competence, autonomy and relatedness and thereby cause a statistically significant increase in the Relative Autonomy Index. This leads to the conclusion that the use of basic principles of Eduscrum in a partly online environment can be effective in fostering secondary school students' autonomous motivation for chemistry.

Discussion

Limitations

The results of this study are subject to limiting factors of different natures. The setting of this study needs to be mentioned first, because the results are not automatically suitable to be generalised to other contexts like other classes, schools, countries, subjects and topics, although the results of the first iteration are promising for other comparable contexts. The random selection of students for the focus groups suggests a representative sample. The interview with the focus groups of the first iteration took place in the same rooms as they followed their chemistry lessons, so the location is known to the students and will likely not have influenced their comments.

An important limitation is formed by the government restrictions on COVID-19 that were introduced during the second iteration. Therefore, the post-test and interviews of this iteration took place in a national lockdown situation whereas the pre-test was conducted in an in-class situation. Besides that, the high absence rates due to quarantine rules complicated the students' teamwork. Furthermore, some of the activities had to be cancelled due to the transition to fully online education halfway through the iteration, so the government restrictions interfered with the design itself. This situation causes the results of iteration 2 to be considered invalid by the researcher and provides a possible explanation for the statistically insignificant results. An increase in the RAI was expected instead of statistically insignificant results, because the first design (based on literature) was effective and the redesign was based on literature as well as the results of the first iteration.

The researchers' teacher relationship with the students is another limitation and this was the case with all students participating in the study. Besides that, the class atmosphere can play a role in this research, because the students could not be randomly assigned to a group (class) due to the school system. Within a class, the students were randomly selected for the focus groups, but they could not change to another class during the iteration. A possible effect of that was minimalized by conducting a pre-test as well as a post-test and by paying special attention to the difference between the pre-test and post-test. Another limitation of this study is made up of the lesson activities that are compulsory for this topic due to the nature of the subject.

Finally, the duration of the study is a limiting factor, because an Eduscrum approach in two iterations of 2,5-4 weeks each was only studied. In order to master Eduscrum the students need some time, so the relatively short duration of the iterations may have affected the results.

Implications

The results of the first iteration show that an Eduscrum teaching approach is likely effective in fostering secondary school students' motivation (for chemistry in this case). Previous research has shown that the support of students' basic psychological needs leads to more autonomous motivation and that intrinsic motivation leads to a set of desirable outcomes, like an increased well-being and higher school results (Ryan & Deci, 2017). This research adds an extra layer by showing that the basic principles of Eduscrum can effectively contribute to the support of the basic needs of students and thus lead to autonomous motivation, which is connected to a set of desirable outcomes as mentioned before.

The role of the team is mentioned specifically to contribute to the support of relatedness and the freedom to schedule tasks to contribute to the support of autonomy. In order to support the students' competence it is crucial to keep the scrum board moderate and clear. This makes the basic principles of Eduscrum a promising teaching procedure that solicits for further evaluation in secondary (chemistry) education.

Future research

The implications of this study suggest that the Eduscrum approach solicits for further evaluation and study, as the limitations of the study do not allow for full generalization. A first step could be to replicate the second iteration in a comparable setting to test the adapted design that was designed after the first iteration. Furthermore, the study could be conducted in different post-pandemic contexts of several classes following different subjects on different schools with an independent researcher which could lead to interesting insights into the generalisability of this study. Finally, this research calls to study the effects of an Eduscrum approach on student results, opening up a new interesting research area within the field of motivation research.

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Appendix 1: Dutch Self-Regulation Questionnaire-Academic

Self-Regulation Questionnaires-Academic (SRQ-A) (Ryan, Connell, & Peeters, n.d.)
Adapted for chemistry classes

A. Why do I do my chemistry homework?

1. Because I want the teacher to think I'm a good student.
2. Because I'll get in trouble if I don't.
3. Because it's fun.
4. Because I will feel bad about myself if I don't do it.
5. Because I want to understand the subject.
6. Because that's what I'm supposed to do.
7. Because I enjoy doing my homework.
8. Because it's important to me to do my homework.

B. Why do I work on my classwork in chemistry class?

9. So that the teacher won't yell at me.
10. Because I want the teacher to think I'm a good student.
11. Because I want to learn new things.
12. Because I'll be ashamed of myself if it didn't get done.
13. Because it's fun.
14. Because that's the rule.
15. Because I enjoy doing my classwork.
16. Because it's important to me to work on my classwork.

C. Why do I try to answer hard questions in chemistry class?

17. Because I want the other students to think I'm smart.
18. Because I feel ashamed of myself when I don't try.
19. Because I enjoy answering hard questions.
20. Because that's what I'm supposed to do.
21. To find out if I'm right or wrong.
22. Because it's fun to answer hard questions.
23. Because it's important to me to try to answer hard questions in class.
24. Because I want the teacher to say nice things about me.

D. Why do I try to do well in chemistry?

25. Because that's what I'm supposed to do.
26. So my teachers will think I'm a good student
27. Because I enjoy doing my school work well.
28. Because I will get in trouble if I don't do well.
29. Because I'll feel really bad about myself if I don't do well.
30. Because it's important to me to try to do well in school.
31. Because I will feel really proud of myself if I do well.
32. Because I might get a reward if I do well.

External Regulation:	2, 6, 9, 14, 20, 24, 25, 28, 32
Introjected Regulation:	1, 4, 10, 12, 17, 18, 26, 29, 31
Identified Regulation:	5, 8, 11, 16, 21, 23, 30
Intrinsic Motivation:	3, 7, 13, 15, 19, 22, 27

Appendix 2: Interview scheme

1. **Information**

2. **Introduction**
    - What do you think of chemistry?

3. **Pre-scheduled interview questions**

Question	Basic need:
• What did you think of working in groups?	R / C
• Did you have enough freedom in planning your work?	A
• Did you get enough help completing the assignments?	C
• What did you think of working with the scrum board?	C
• What did you think of the choice tasks?	A
• Did you enjoy working in this way?	CAR

Possible follow-up questions
- Explain please…
- Why?
- What do you think about that?
- Give me an example please.
- But what was it, that you didn't like?
- Mention a few pro's and con's please.

4. **Suggestions for improvement**
    - How could working in groups become better?
    - What could be better when planning your work?
    - How could help with completing assignments become better?
    - What could be improved on the team board?
    - What could be done better about the choice tasks?
    - How could this way of working become more fun?

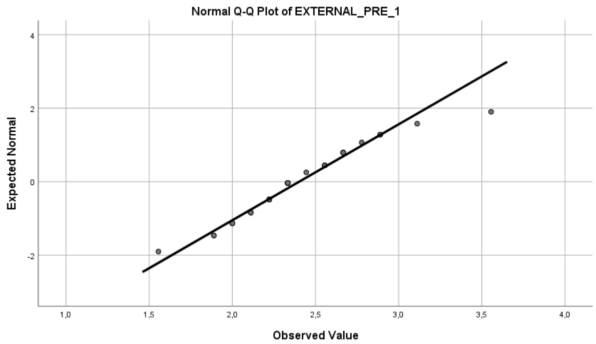
5. **Acknowledgments**

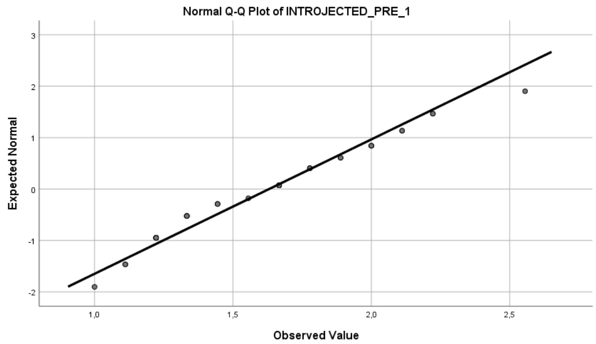
Appendix 3: Coding rubric

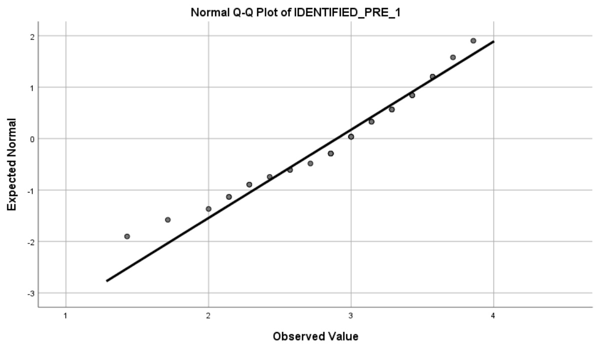
Construct	Description	Relation-ship	Typical example	Code
Competence	Perceived support of competence	Positive	*“You can just help each other et cetera and that is very helpful and after that you have, after that, if that doesn't work, then you still have the teacher, so I really liked that.”*	C+
		Negative	*“Well, it looks a little complicated and so on. And then yes, you had explained it, but yes, then you have to start it yourself at home. And then you actually don't know anymore.”*	C-
Autonomy	Perceived support of autonomy	Positive	*"And it is also nice that you can decide for yourself when you actually do something, as long as you just always do it."*	A+
		Negative	*"Yes then it didn't really feel like you were planning yourself..."*	A-
Relatedness	Perceived support of relatedness	Positive	*“I thought it was fun [sociable], that's an advantage.”*	R+
		Negative	*“Yeah, but I don't know, he just didn't and he just didn't interfere, he just did what he was going to do himself and otherwise he didn't really interfere with the group.”*	R-
Recommendations	Recommen-dations for redesign	-	*“Yes, uh, I think, but I just like that better, just that [column] ‘doing’, that can really be removed for me, because that is so much work to drag all those things. It took us really ten minutes to just drag those things, or something like that, that's a bit of a waste of your time.”*	T*

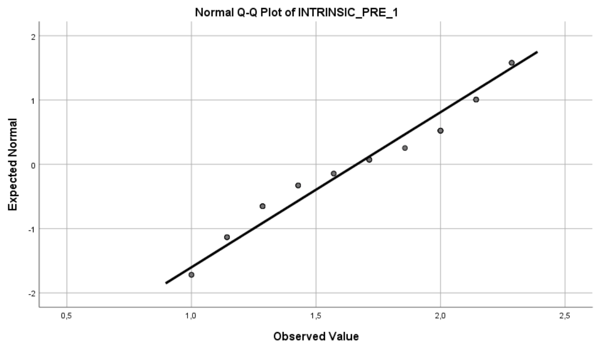
Appendix 4: Q-Q plots for t-test

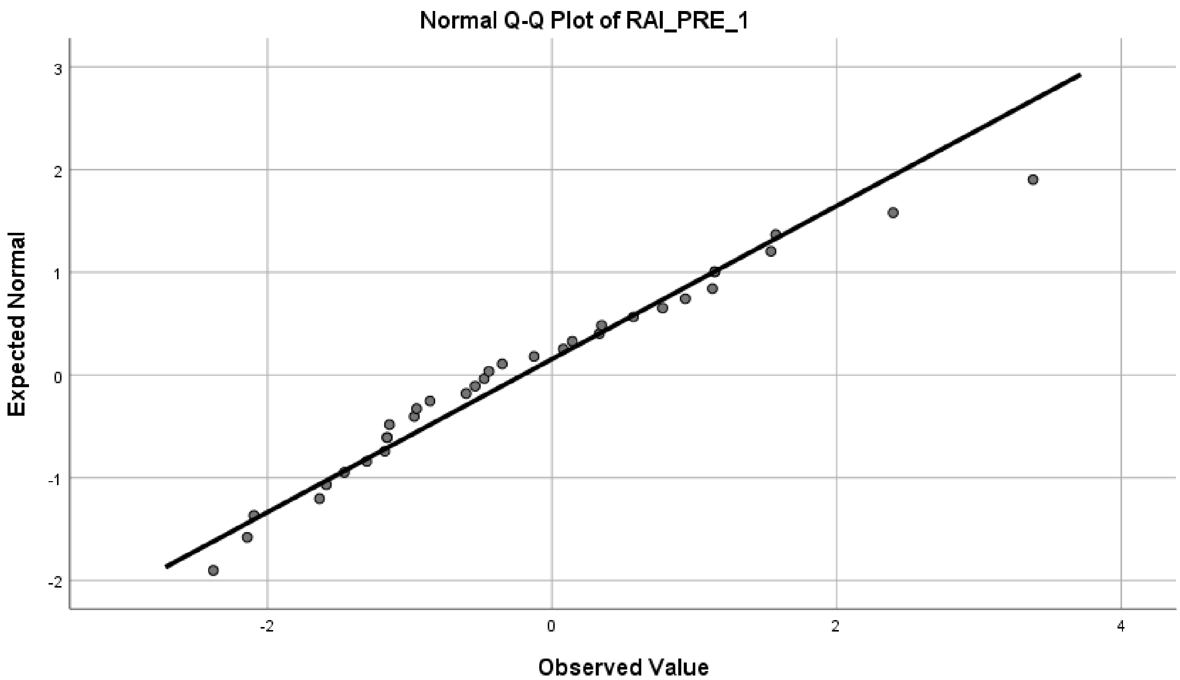
Q-Q plots of pre-test iteration 1 for t-test



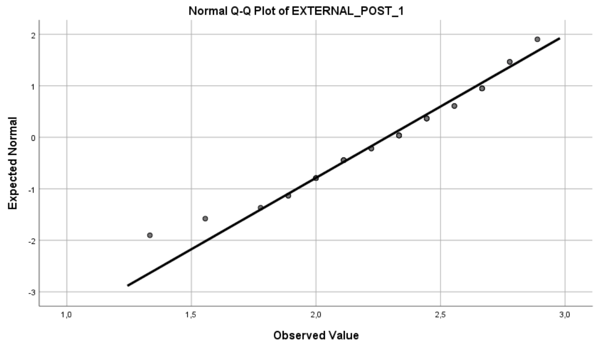


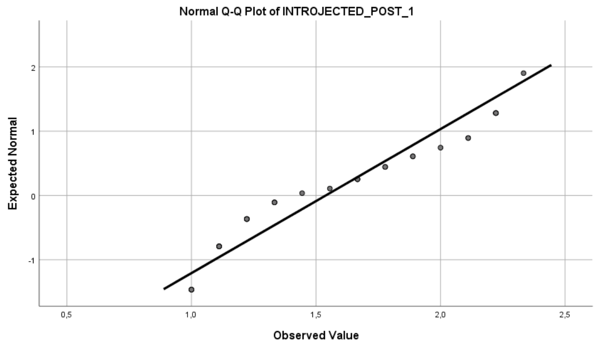


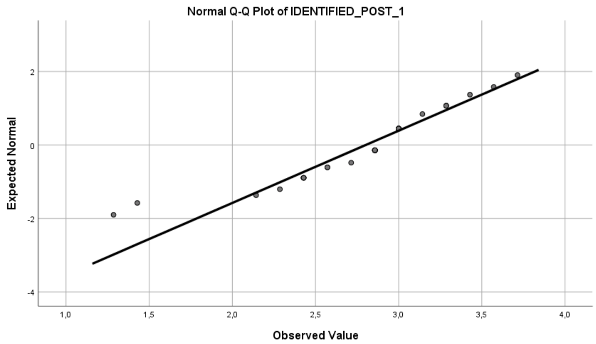


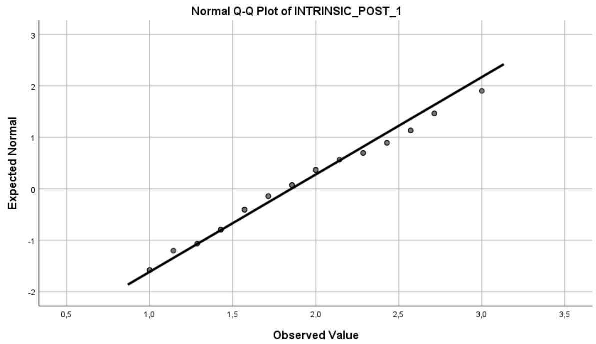


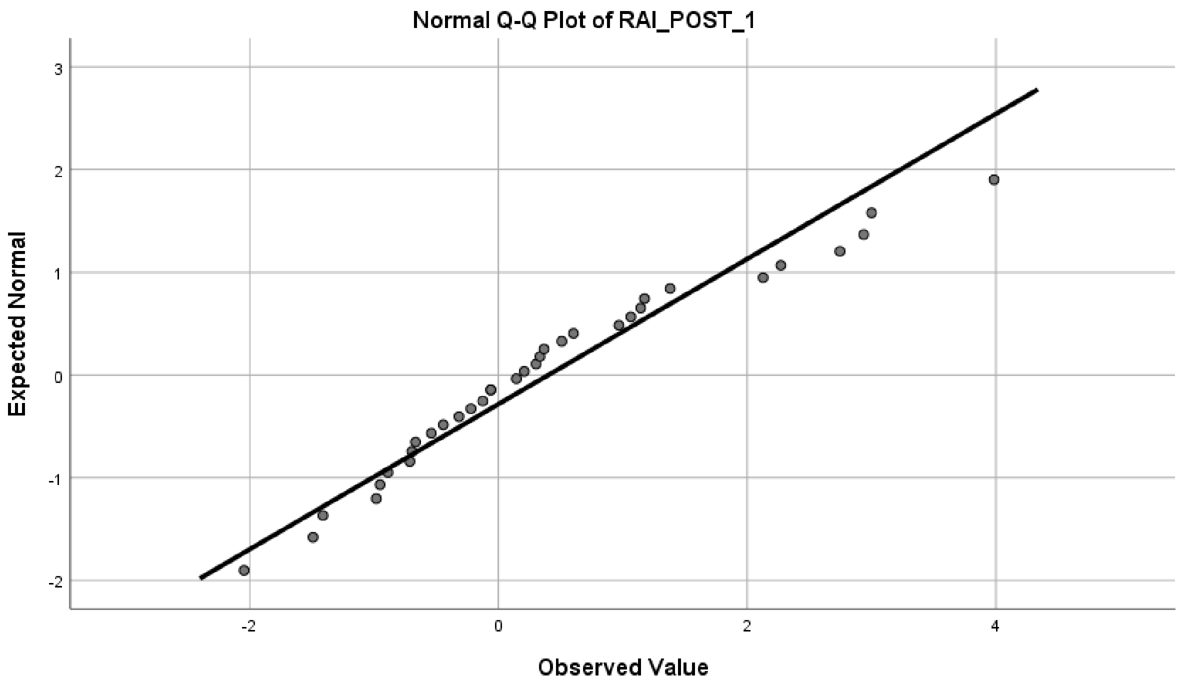
Q-Q plots of post-test iteration 1 for t-test



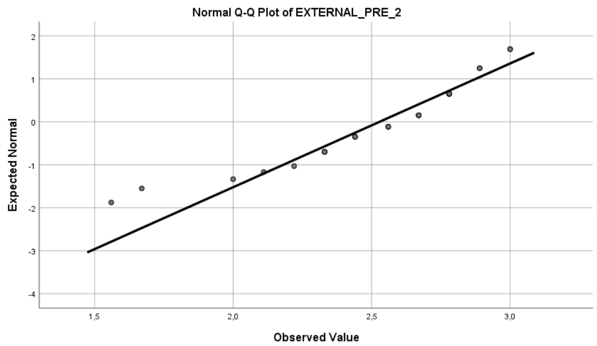


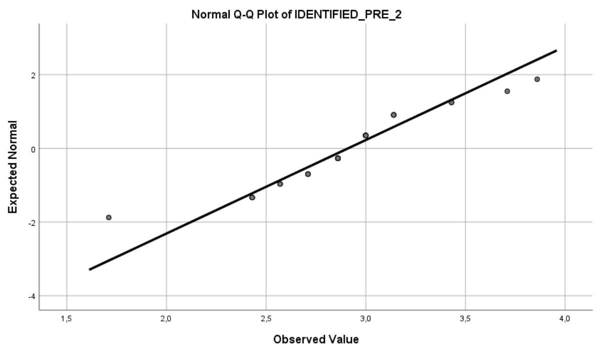


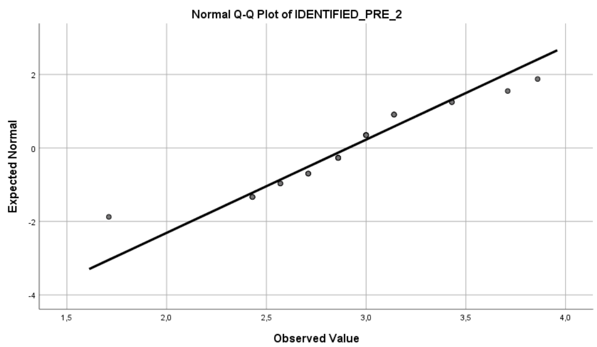


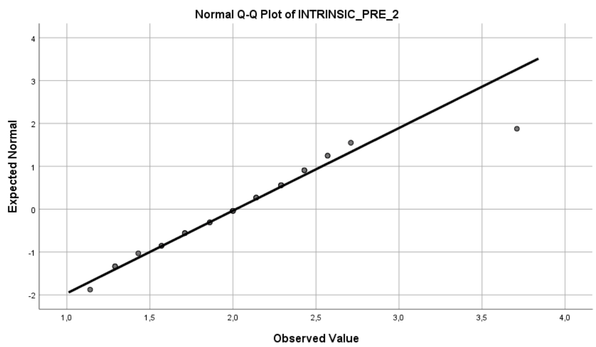


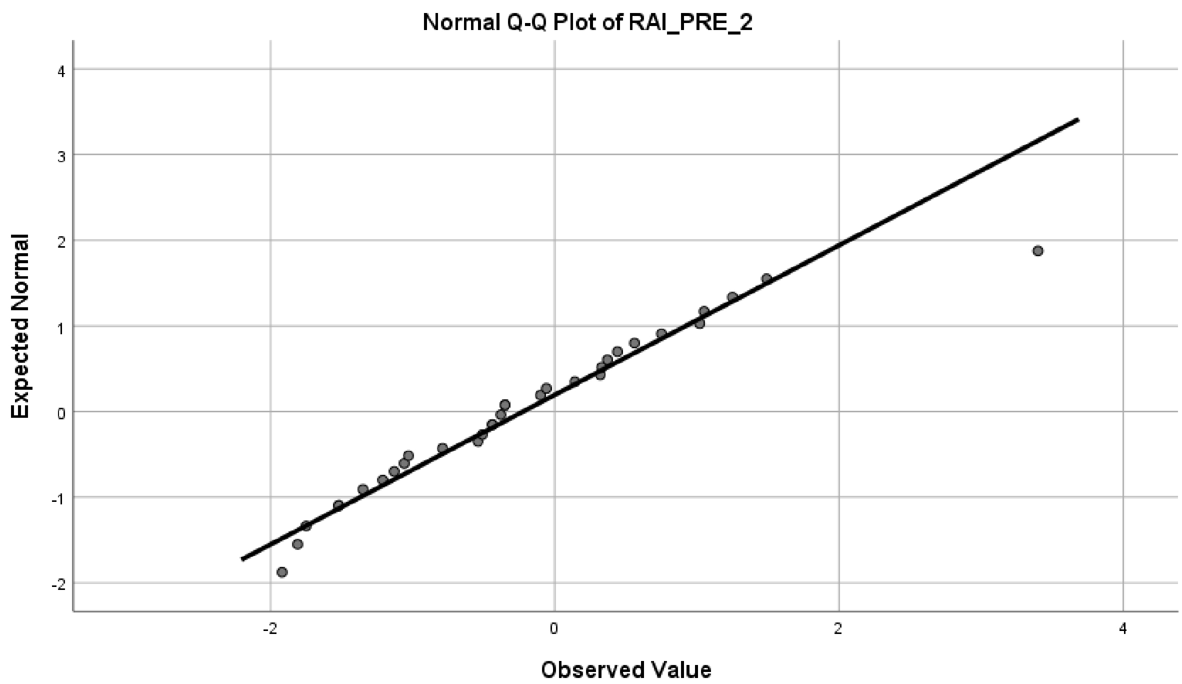
Q-Q plots of pre-test iteration 2 for t-test



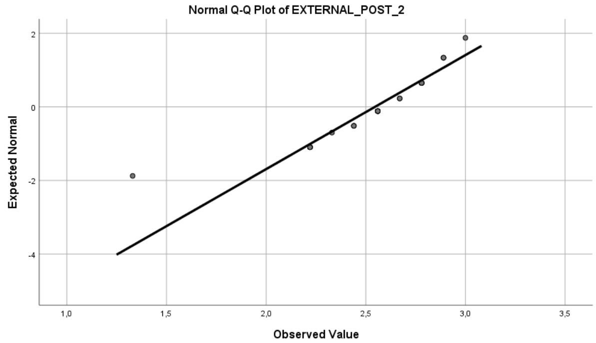


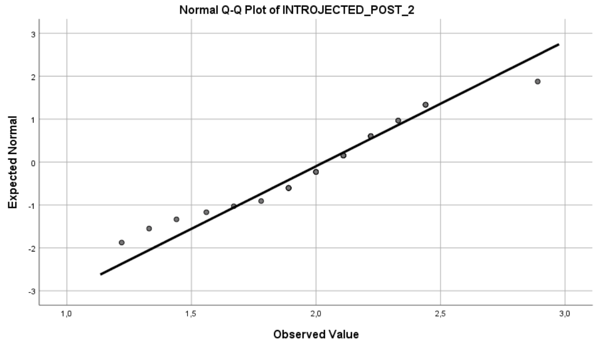


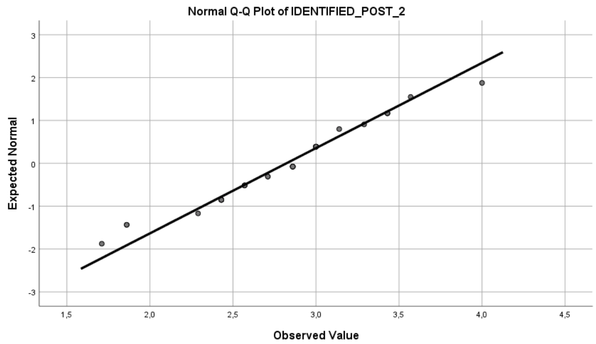


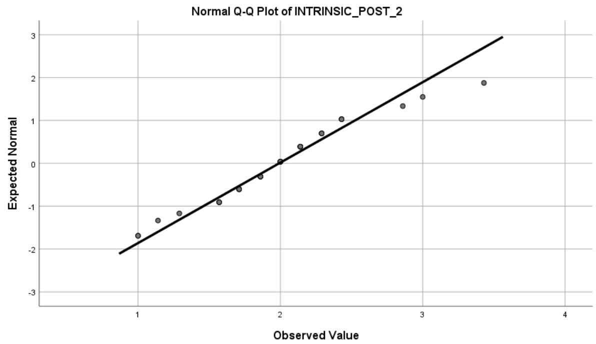


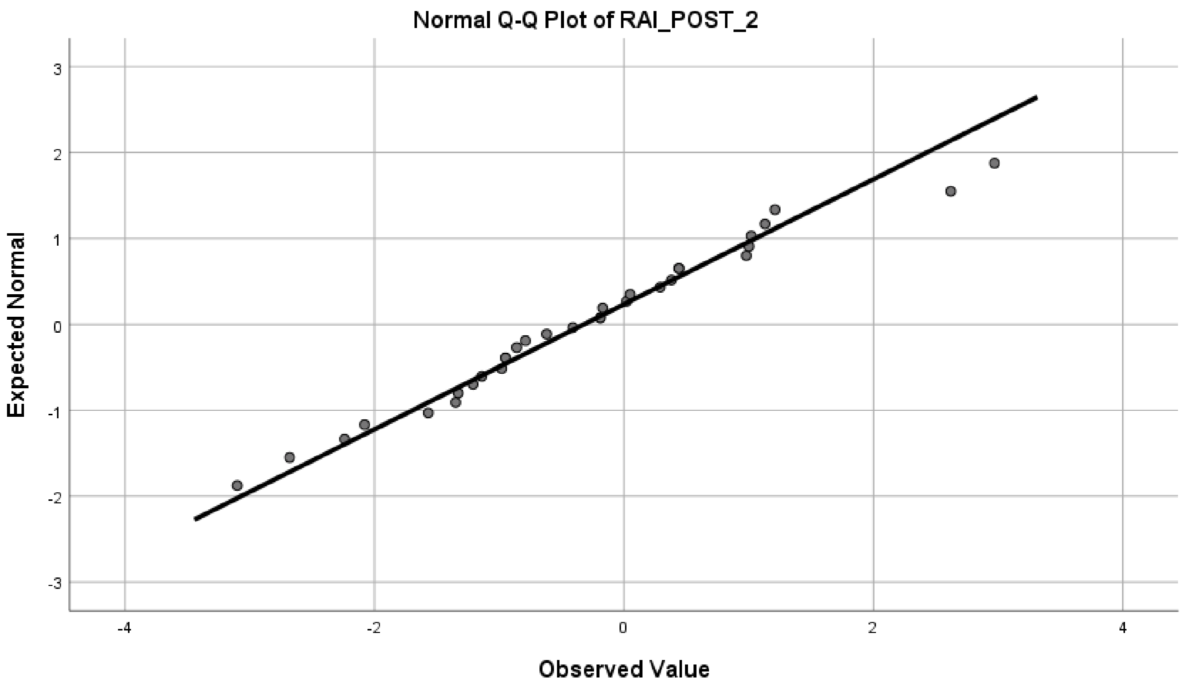
Q-Q plots of post-test iteration 2 for t-test





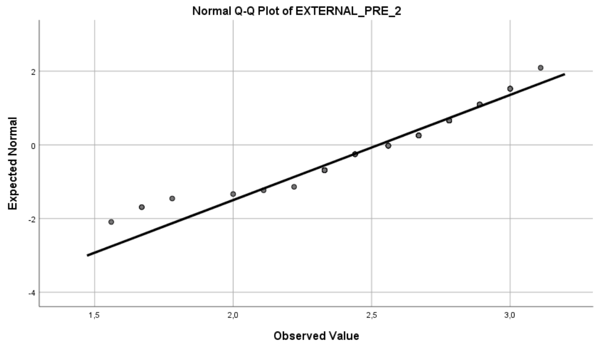


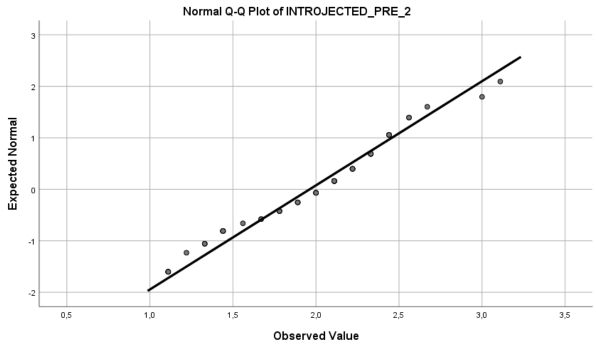


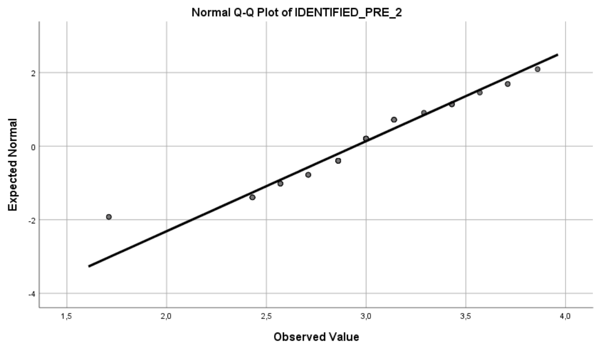


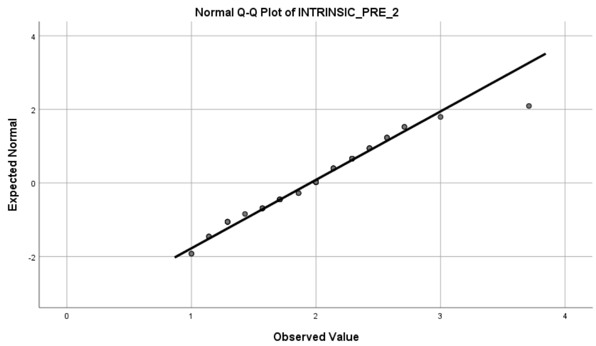
Appendix 5: Q-Q plots for ANOVA

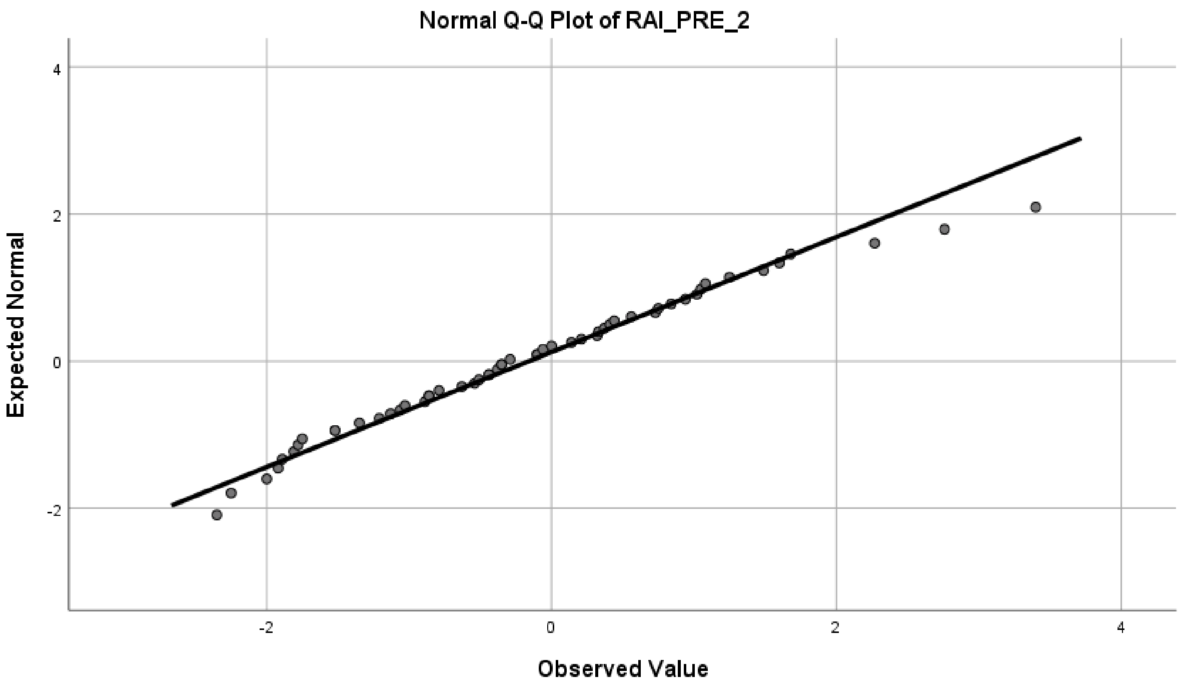
Q-Q plots of pre-test iteration 2 for ANOVA



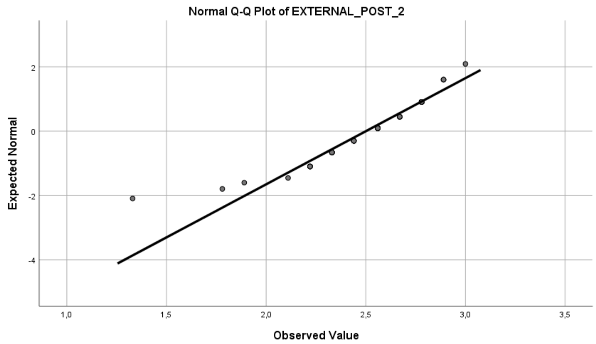


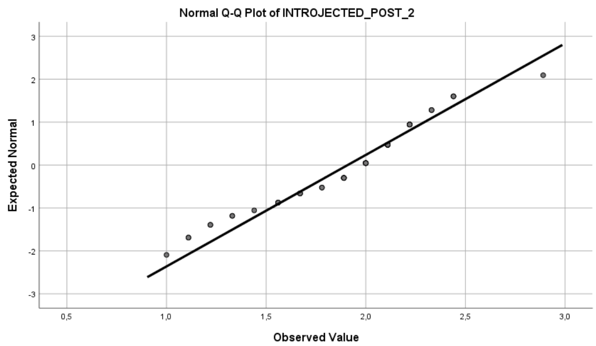


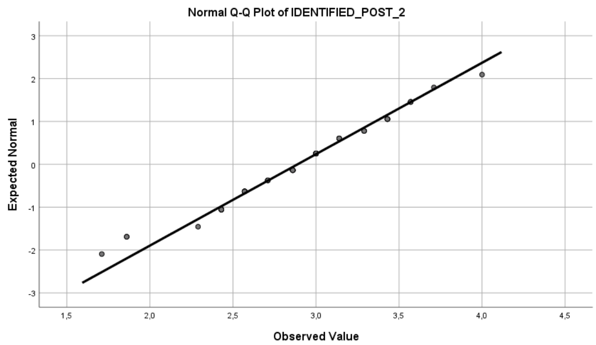


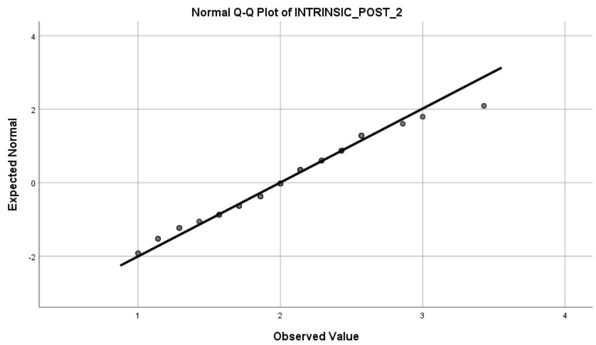


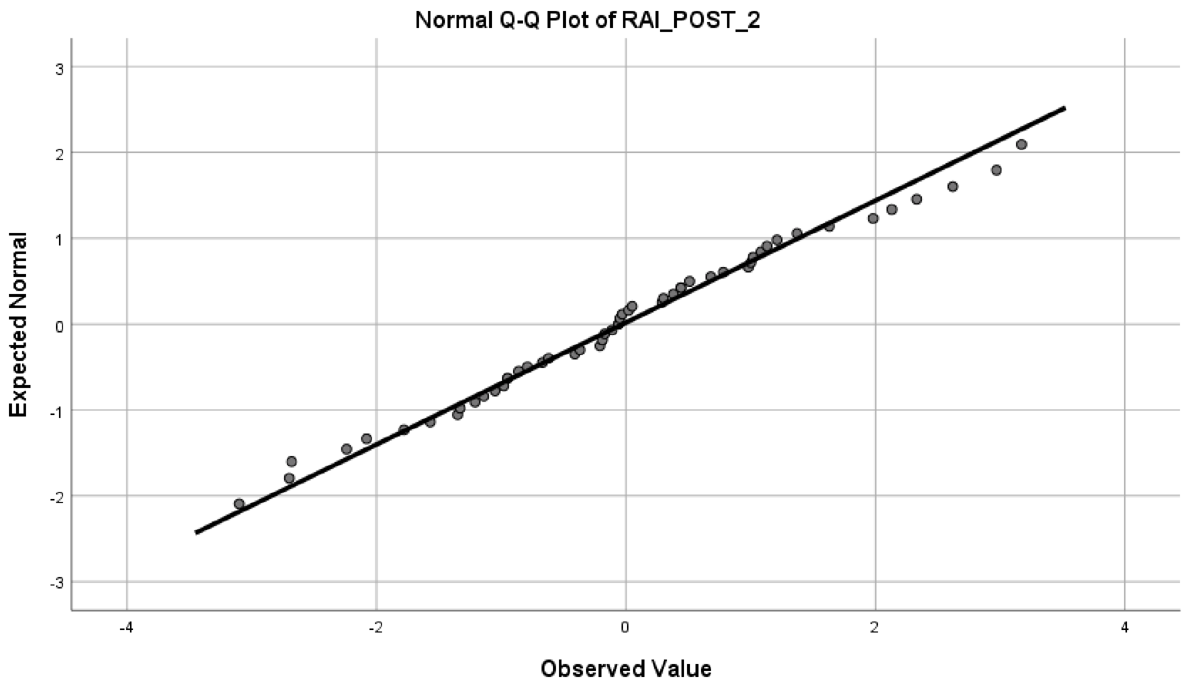
Q-Q plots of post-test iteration 2 for ANOVA











Appendix 6: Eduscrum in practice

Just like common Scrum, an Eduscrum process consists of a number of roles and ceremonies (Deemer et al., 2010). The product owner (teacher) initiates the Eduscrum process and defines the tasks in a product backlog. The tasks are scheduled via a sprint planning and represented on a Scrum board. The teacher then releases the sprints; periods of working on a set of tasks. The teams of students work on the set of tasks during the sprint and use the ceremonies of a stand-up meeting, sprint review and sprint retrospective during the sprint. The adapted cycle of Eduscrum is given in figure 13. Different aspects of the Eduscrum process are further analysed below and applied to a chemistry Eduscrum process.

Product owner
The product owner is the initiator of the Eduscrum process, the teacher, who is responsible for the final product (Deemer, Benefield, Larman, & Vodde, 2012). The teacher defines the final product that will be developed by the team in the product backlog, which is a certain final assignment or grade for a test in the case of Eduscrum. The teacher also coaches the team like a Scrum master would in common Scrum, so the teacher serves the two roles of product owner (project manager) and Scrum master at the same time (Hu, Cleland, & Steele, 2018), whereas in common Scrum this requires two different people (Deemer et al., 2012).

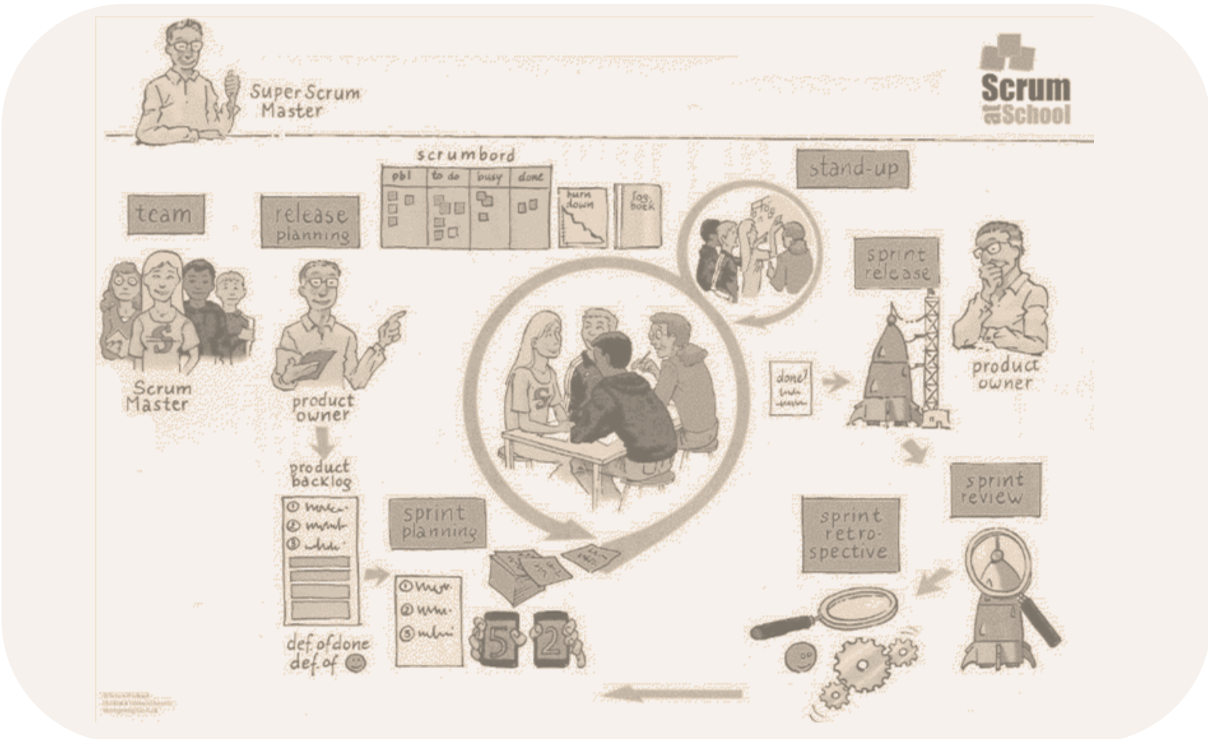


Figure 13: The Eduscrum cycle (Source: Bongaerts, 2018; p.16)

Product backlog
The product backlog is a list of the tasks that have to be finished during the process, which typically includes doing assignments from the chemistry book, reading chemical literature, carrying out a practical, or watching an explanatory video. The list of tasks should be priority-ordered and each item should be given an estimation of the effort needed to complete it (Deemer et al., 2012), preferably by the students.

Sprint planning and Scrum board

The sprint planning is a ceremony where the team members select tasks from the product backlog that will be executed during the coming sprint (week). The tasks are represented on the Scrum board, where tasks move through columns with the titles: 'To Do', 'Work in Progress' and 'Done' (Deemer et al., 2012). A clear definition of done is needed to clarify when a task can be considered finished (Bongaerts, 2018). For assignments from the book this would simply be the completion of the assignment and the process of checking the answers. For Eduscrum the definition of done could be given as a list of requirements to a final assignment or as an overall minimum grade the students need to receive for an end-of-chapter test.[3]

Sprint

The actual sprint is the process of working on tasks, for the duration of a week, for instance. The teacher leads the stand-up meetings in which the team gathers round the Scrum board and discusses their progress. The burndown chart can be used as a straightforward tool to provide the product owner and the team with insight into their progress (Deemer et al., 2012). At the end of a sprint the sprint review and sprint retrospective take place. The sprint review is meant for reviewing the work itself. The sprint retrospective is a way of reflecting on the group process. It is important not to focus on the weakness only, but also on the strengths of the group process (Deemer et al., 2012).[4]

Example of Eduscrum sprint

In an Eduscrum process a chemistry teacher could initiate an Eduscrum cycle about chemical reactions. First, the teacher would define the tasks belonging to that topic. For example, doing assignments 1-12 from the book and carrying out a practical about decomposing water. All tasks about chemical reactions that the chapter contains should be listed in the product backlog. Then the student teams should be formed. This can be done in different ways, such as the following ways:

- The students form teams themselves (likely with friends);[5]
- The teacher forms random teams;
- The students form mixed teams based on personal qualities of the students.[6]

Each student team receives a Scrum board to summarize their Eduscrum process. When the first sprint (week) starts, the students select the tasks from the product backlog that belong to the first week. Those tasks are moved to the 'To Do'-column. Then the students start working on the assignments and during the week, the tasks can be moved to 'Work in Progress' and 'Done.' During each lesson the student team gathers round the Scrum board and discusses their process, after which they continue with their tasks. At the end of the cycle, the students are done when they are able to receive a certain grade for their test.

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[3] For education it can be important to assess students individually. However, Eduscrum focusses on teamwork, so it suggests group assessment. In order to meet the conditions of the current common summative educational system, individual grades should be guaranteed. In this study, the students were granted individual marks for a test. Other possibilities are a division of the project in 2 parts, one for group work and one for individual performance or the use of a metric (to define what percentage of the group mark should be counted for a particular student) in order to enable assessing individual performance in group projects (Hu et al., 2018).

[4] In this study the stand-up meetings, sprint review and sprint retrospective were partly on location and partly online, due to the COVID-19 measures (discussed on p.22-23). A burndown chart was not used in this study.

[5] This method was used during the pilot and the first iteration.

[6] This method was used during the second iteration.