SUPPORTING THE AUTONOMOUS MOTIVATION OF HIGH SCHOOL STUDENTS FOR PHYSICS

A mixed-methods study into which elements of a physics lesson series support the basic psychological needs for students who have not chosen physics in their subject cluster choice.

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Abstract

The school system of the Netherlands calls for 9th grade students to determine their school subjects for the subsequent years midway through the school year. This choice is called the "profielkeuze" or subject cluster choice. Teachers of electives are then faced with a specific challenge regarding the motivation of students who have not chosen their subject, as this choice indicates a lack of autonomous motivation for their subject going into the rest of the school year. In this study, principles of the Self Determination Theory were used to design a lesson series catering to the needs of students following a course they will not take in subsequent years. This lesson series spanned one full chapter and included elements students, through a questionnaire and focus group, indicated that they wanted: to work together, practice exercises, to do practical assignments, and learning to study and formulate answers for the test, as well as working with PowerPoint presentations during instructions.

Prior to and at the end of the intervention, the motivation of the students was measured using the SRQ-A questionnaire, adapted to the subject of physics, and from the answers students' Relative Autonomy Indexes (RAI) were calculated. These results showed that at the end of the intervention students from the Intervention Group demonstrated a stable RAI,

i. e. a stable level of autonomous motivation, while the Control Group had their RAI decrease significantly, demonstrating a shift to more controlled forms of motivation. During follow-up semi-structured focus groups, students from the Intervention Group reported feeling supported in their basic psychological needs by the learning activities presented in the lesson series, whereas students from the Control Group had to find other sources for support. These results may be used to better cater to the needs of students who feel they will not need a subject later in life.

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Introduction

In several countries, including the Netherlands, secondary school students have to choose the subjects they are going to take in later years in the middle of the 9th year. This is called the subject cluster choice or "profielkeuze". This choice excludes compulsory courses, like Dutch, English, and some elements of mathematics (Ministerie van Onderwijs, 2016b, 2016a), but all other courses are electives. This choice being made somewhere during the school year, leads to a division within every class for those elective courses. The students who have chosen the course will be motivated to study, knowing they will have the course again the subsequent year. Meanwhile, the students who have not chosen the elective will experience controlled motivation, through tests, as they still have to finish the school year (Waterstaat, 2014). This kind of motivation is fleeting and relies heavily on how important students deem a test to be. Because of this, it's very hard to autonomously motivate some students, which would be preferred, as autonomous motivation is connected to positive feelings and better performance, whereas controlled motivation goes hand in hand with feelings of shame (Sierens & Vansteenkiste, 2009).

Autonomously motivating divided groups like these 9th grade classes for subjects such as physics, chemistry, geography, history, and some languages thus is a difficult topic to address, but is a problem nonetheless. PISA studies show that intrinsic motivation , the most autonomous form of motivation, decreased between 2003 and 2012 for students in the Netherlands. (OECD, 2013) This points to a possible loss of performance and students well-being, and outside forces, such as tests, to becoming a more and more prominent source of motivation.

Even if students do not take pleasure in the topics or activities themselves, there are ways they can be autonomously motivated. One theory on motivation is the Self-Determination Theory (Ryan & Deci, 2000), which poses that supporting students' basic psychological needs will increase autonomous motivation. However, applying this theory is not straightforward and teachers don't have unlimited time to adjust to every specific group of students (Harmsen et al., 2019; Walker et al., 2019).

In this study, influences on the motivational profile, i. e., the level of autonomous motivation relative to the controlled motivation, of 9th grade students in the Netherlands are investigated. Although this research was done for a particular school system, the results could be valuable for any teacher dealing with students who are experiencing controlled motivation. There is a wealth of studies on supporting basic psychological needs in education in order to make students' motivation more autonomous (e.g., De Meyer et al., 2016; Leo et al., 2022; Raižienė et al., 2018), but the specific situation as it is in the Netherlands, regarding the subject cluster choice, is largely unstudied. The research question and sub-questions this research aims to answer can be found at the end of the Theoretical Background.

Theoretical Background

Motivation is the reason behind why we do or don't do activities. Academically speaking, Gopalan (2017) stated "students' level of motivation reflects on their engagement and contribution in a learning environment". High engagement and contributions to the learning activities are preferred in the classroom, therefore we would want students to become more motivated. However, as already touched upon, "more" motivation does not equal "better" motivation. Autonomous motivation is the most desirable type of motivation, due to the effects it has on students' well-being (Sierens & Vansteenkiste, 2009).
Motivation has been studied for a long time. Here, some theories of motivation through time are presented, concluding with the theory most taken into consideration in this thesis: the Self-Determination Theory.

A Brief History of Motivational Theories

With roots in Darwin's evolution theory, the **behaviorism** approach is one where one looks at people's instincts, drive, and ability to adapt: learning something from a new experience has a positive effect on the survival, which is why someone would keep doing those new things (H. Heckhausen, 2018). This motivational theory implies that people are not in control of certain behaviors, because these behaviors have been automated for survival. New things can be learnt from changes in behavior.
For education, Thorndike proposed two 'laws of learning' (OECD 2010, Chapter 2). The 'law of effect' stated a rewarding effect reinforces you to do something: if a certain behavior has a positive outcome, you are more likely to do it again. These behaviors are strengthened by repetition and practicing them: the 'law of exercise'.

However, personality and individuality was taken into account after a while as psychologists became interested in exactly *how* information was processed and led to decision-making. This is called **cognitivism**. As said by Erik de Corte (OECD 2010, Chapter 2):

"Instead of being satisfied with studying externally-observable behaviour, the aim was to analyse and understand the internal mental processes and the knowledge structures that underlie human behavior."

From cognitivism, a new era arose: **constructivism**; learning does not happen when you *get* information, but once you *interpret* that received information (OECD 2010, Chapter 2). A theory that built upon that idea, was socio-constructivism. In **socio-constructivism**, it is believed that learning does not happen inside of the mind, but rather in interactions with other people. Learning was no longer an activity one did on their own, but one that happened in a social context.

Self Determination Theory

The **self determination theory** builds upon those previous ideas of expected outcomes, and interaction. In this section, the SDT will be explained extensively, as it is the theory this research is based on most.

Illustrated in *figure 1* is the continuum of motivation posed by Ryan and Deci (2000) as part of the Self-Determination Theory and reinterpreted by Visser (2017):

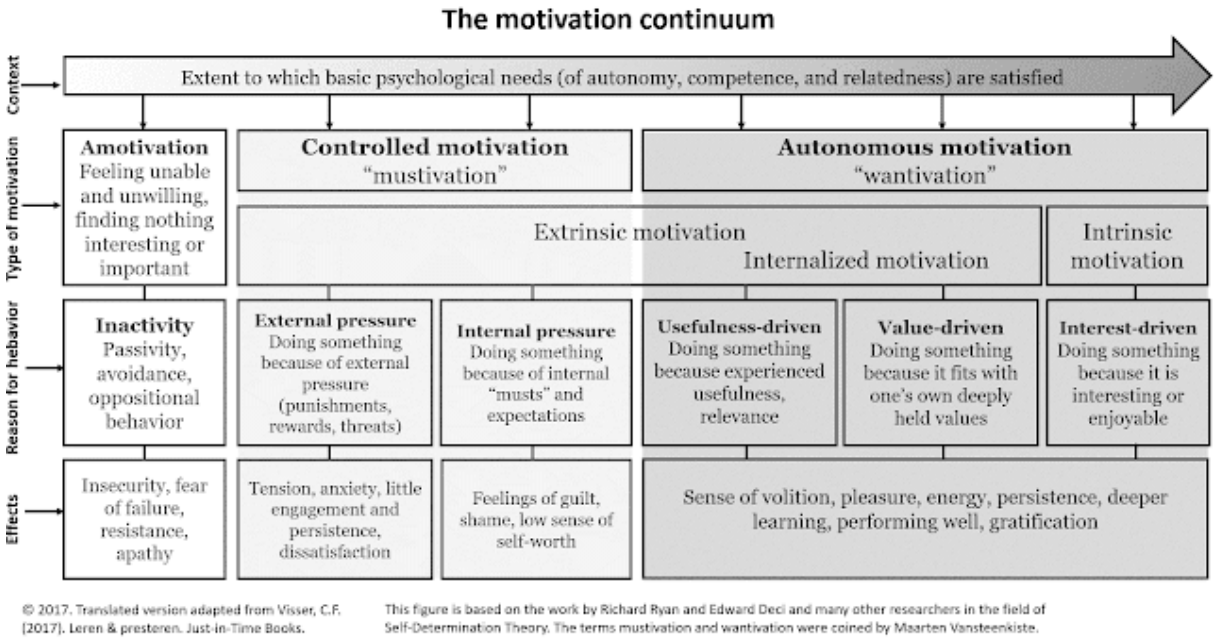

Figure 1: The motivation continuum according to the Self-Determination Theory.

Motivation comes in many different forms and for many different reasons. The kinds of motivation differ due to what is called the "locus of causality" (Deci & Ryan, 2000), which is a term to indicate where the influences on your decisions and motivation come from. "Controlled motivation" has a perceived locus of causality that's external, as seen in *figure 1*, while the "autonomous motivation" has an internally perceived locus of causality.

On the far left side of the motivation continuum is amotivation (Deci & Ryan, 2008), which is the absence of any motivation: there's no inclination to engage in the activity at hand. Next to amotivation is controlled motivation, which is the kind this research aims to turn into a more autonomous kind of motivation. Controlled motivation involves pressure, either external or internal. External pressure works with rewards and punishments set by other people and is most explicit: extrinsic regulation. Introjected motivation, in *figure 1* referred to as internal pressure, is less visible, since it is a pressure applied internally due to not wanting to fail or let other people down. Even though this last one is internally decided, the reasons for feeling the pressure are to satisfy some external influence (Ryan & Deci, 2012).
As seen in the bottom row of *figure 1*, controlled motivation has negative effects on a person's well-being: they induce anxiety, feelings of guilt and shame, dissatisfaction, and a low sense of self-worth.

Autonomous motivation contains three forms of motivation. One of which is intrinsic motivation: doing something because it is enjoyable or interesting. However, it might not be very realistic to expect students to start to like physics to that extend within one lesson series

(Corpus et al., 2009), as changes in intrinsic motivation usually take a longer time and are small even within a year. Thus, this research aims to achieve the other forms of autonomous motivation. Identified motivation, in *figure 1* referred to as usefulness-driven, is felt when the relevance of the activity is understood (Ryan & Deci, 2012). Value-driven motivation is the motivation that is felt when doing something that lies within a person's own held values. Autonomous motivation gives feelings of gratification and promotes deeper learning and a better performance (Cerasoli et al., 2016; Sierens & Vansteenkiste, 2009; Vallerand et al., 2008). Due to these differences in related feelings between controlled and autonomous motivation, developing a more autonomous kind of motivation is preferred.

The intrinsic, identified, introjected, and extrinsic forms of motivation can be measured using the SRQ-A questionnaire (Sierens & Vansteenkiste, 2009). This questionnaire thus gives insight into the different forms of motivation a person experiences: their motivational profile. The Relative Autonomy Index (RAI) is a measure of the ratio in which autonomous motivations and controlled motivations are present and can be calculated using the following formula (Ünlü, 2016):

Equation 1: Relative Autonomy Index calculation

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

A higher value RAI indicates a more autonomous motivational profile, whereas a smaller RAI indicates experiencing more controlled forms of motivation.

Influencing the different forms of motivation someone experiences can be done through support of the basic psychological needs. Ryan & Deci (2000) state people have three **basic psychological needs**, and if these needs are met, people are more autonomously motivated to do something and able to learn. Thus, supporting or thwarting these needs, changes the motivation people feel to do something.
These needs are the needs for autonomy, relatedness, and competence (Cerasoli et al., 2016).
The need for **autonomy** states people need to be able to make their own choices, or at least think they have a say in the matter. For education, this means learning needs to emphasize choice rather than control.
The need for **relatedness** is satisfied when people's feelings are acknowledged, which happens in positive interactions between people.
Lastly, the need for **competence** states people need to be able to understand the purpose and personal importance for each learning activity. On top of that, they need to feel that they are able to do the given task.

Research Questions

The above-mentioned theory and the conducted questionnaires and focus groups as explained in the Methods section, will be used to answer the following main research question:

"What elements of a physics lesson series support the basic psychological needs for students who have not chosen physics in their subject cluster choice?"

Based on the theoretical background, the autonomous motivation for students is expected to increase when attention is being paid specifically to meeting the basic psychological needs from the Self-Determination Theory. To be able to answer the research question properly, sub-questions were formulated.

1. According to students, what are candidate elements of a physics lesson series that support their basic psychological needs?

2. To what extent does an environment that supports the basic psychological needs influence the motivational profile of students during a physics lesson series?

3. What do the students report on the support of their basic psychological needs by the different elements of the lesson series?

Conjecture Map

A large part of this research was designing a lesson series. In order to keep in mind the goals of the design, a conjecture map was used (Wu and Chen, 2018) (Sandoval, 2013).
The conjecture map used in this research was completed after the first elements of the research (the questionnaire and the design focus group) were conducted.

Hypothesis

By implementing the design elements as found in answer to sub-question 1 in a semi-structured focus group, the basic psychological needs are expected to be supported. This will then increase the Relative Autonomy Index, i.e., the ratio of autonomous motivation to controlled motivation.

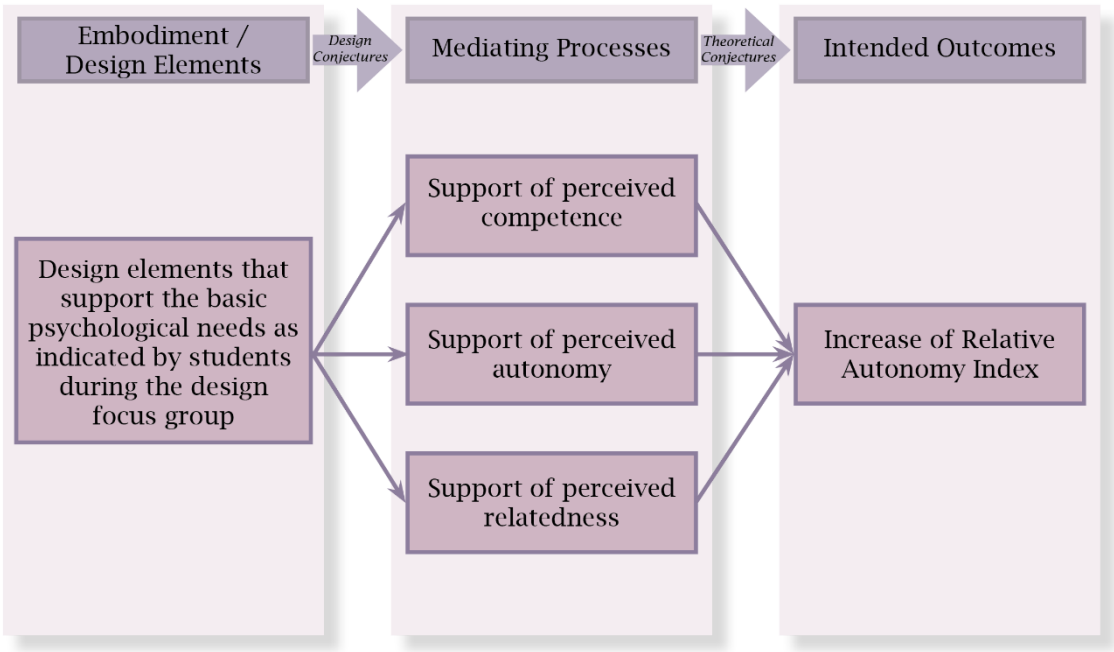

Figure 2: A concept of a conjecture map as used in this research.

Methods

Overview

The research was conducted according to the structure illustrated *figure 3*:

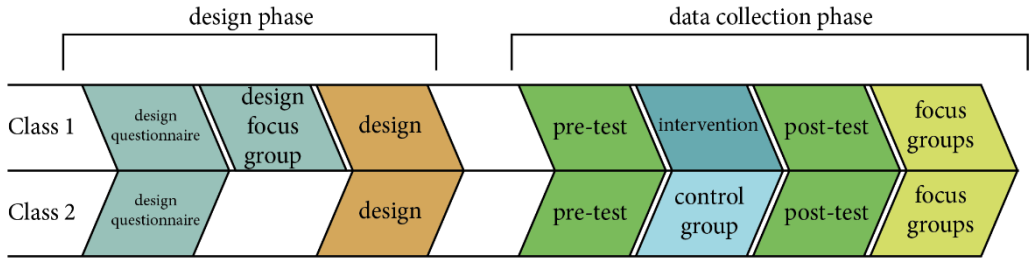

Figure 3: A visual representation of the structure of the elements in this research.

The design phase focused on answering the first sub-question. The **design questionnaire** and semi-structured **design focus group** helped in finding design parameters which were then implemented in the **design** of a lesson series spanning a chapter.

The lesson series was then used as the intervention in the **data collection phase**. In that phase a **pre-** and **post-test** were conducted, which measured the levels of autonomous motivation. These results will answer the second sub-question. The third sub-question is answered through conducting semi-structured **focus groups**.

Context

The Dutch School System

In the Dutch school system, every 9th grade student has to decide on a "subject cluster choice", or "profielkeuze", about halfway through the school year, though most students will have started the decision-making process sooner (Driel et al., 2010). The subjects they do not choose, they will have to finish in the third year, as the government decided on a basic knowledge curriculum students of certain levels of education need to have (Waterstaat, 2014). After the third year, those subjects are dropped.

During this decision-making process, the class experiences a divide between the students who will and who will not choose certain subjects. This divide is seen in the students' motivational profiles, i. e., the forms of motivation they experience. Teachers have to navigate teaching to students with these different kinds of motivation.

Participants

The participants of this study were 9th grade (14- and 15-year-old) students in a physics course in pre-university secondary education in a large, urban school in the center of the Netherlands. Due to the students' age, the focus groups conducted in this research required informed consent from the students and their parents.
Even though the principal target group were the students that have not chosen physics in their subject cluster choice, students who did choose physics participated in the intervention as well, in order to research an authentic environment. Moreover, the relative sizes of the group of non-choosers and the group of choosers varied greatly. The participating students were from two parallel classes, which were taught by different teachers. The Control Group and Intervention Group both consisted of 24 students each.

Instruments

Design Questionnaire (First sub-question)

The questionnaire prior to the design focus group was distributed amongst five 9th grade classes of pre-university secondary education with 20 to 25 students each.

The design questionnaire consisted of nine multiple choice questions and one open question, and was composed specifically for this research. Students administered their answers anonymously.

Table 1: The questions and answer options to the questionnaire on students' feelings toward the subject of physics distributed amongst over a hundred students.

Question/statement	Answer options
Will you be choosing physics in your subject cluster choice?	"Yes", "No", and "I don't know"
I am good at physics. I feel like we move through the topics too fast. I think the exercises in the physics lesson book are too easy. I think practical assignments in physics are fun I would like to do practical assignments more often during physics lessons. I prefer working on physics with other people. I like working with a classmate who is good at physics. I like to help out fellow classmates who are less skilled at physics than I am.	Students were asked to rank how much they agreed with the statements: I disagree I slightly disagree Neutral I slightly agree I agree
What do you need in order to finish the physics course as well as possible this year?	Open question

According to the answers to these questions, questions for the semi-structured design focus group were constructed. These questions can be found in the Results subsection relating to the design questionnaire.

Focus groups (First and third sub-questions)

To gain more insight in how to implement the answers and suggestions students provided, focus groups were held.

However, focus groups have some flaws that need accounting for. One issue in focus groups worth discussing is the so-called 'dominant voices', where certain members of the focus group will dominate the conversation with their own opinion. (Smithson, 2000) During the focus groups held in this research, students who talked less were offered the opportunity to talk in quiet moments. Moreover, group dynamics of the class were taken into consideration in order to make every participant feel safe enough to speak their mind. Exaggeration, minimization, or withholding information (Hollander, 2004) are less likely to occur in environments where the participants feel equal.
On top of that, the interpretation of the moderator's behavior might have students answer questions in a way that they think will please the moderator. It was therefore important to react in the same way to different kinds of answers.

Despite the disadvantages of focus groups discussed above, they were still the preferred method of data collection as opposed to interviews, as they were quicker and interaction between students could take place. (Kitzinger, 1994) Through these interactions, students' actual feelings toward the topic can be understood, and the students can construct opinions together (Acocella, 2012) and feel validated by experiencing other students having the same feelings. Additionally, the interaction between students makes that the researcher's attendance is a less prominent factor (Hollander, 2004).

Design Focus Group (First sub-question)

The design focus group was conducted in the Intervention Group, as seen in *figure 3*. Four students, all female, participated in the focus group. Three of the four students already knew they would not choose physics in their subject cluster choice. The questions for this semi-structured focus group were determined by the outcome of the design questionnaire.

Second Focus Groups (Third sub-question)

The second focus groups were conducted a week after the intervention had ended and served the purpose to get a better insight into the results from the SRQ-A questionnaire.

Two focus groups were held in the Control Group: one of which the students were not going to choose physics in their subject cluster choice (NoC), and one in which they were (YesC). Three focus groups were conducted in the Intervention Group. However, the number of students choosing physics in the Intervention Group (3 out of 24) compared to the Control Group (11 out of 24) was much lower, making it so there was no focus group with the ones who were choosing physics. Instead, one focus group had participants who still had doubts about choosing physics (IDI). Additionally, the amount of students *not* choosing physics in the Intervention Group called for two groups of non-choosers (NoI1 and NoI2) instead of the one held in the Control Group.

Table 2: Distribution of the participants of the different focus groups held after the intervention.

	Male participants	Female participants	Total participants
NoC	0	6	6
YesC	2	1	3
NoI1	3	1	4
NoI2	4	0	4
IDI	0	2	2

The questions asked to guide the second focus groups were as follows:

1. What did you think of the subject of physics during chapter 3?
2. Did you think it was an easy or difficult chapter?
3. Did you feel like you yourself influenced what happened during the lessons?
4. What did you think of the ambience in class during the activities you did? For example making exercises, doing a practical assignment, etc.
5. Are there any other remarks you want to make about the education your received during chapter 3?

Follow-up questions were kept to a minimum, only asking for clarification or examples. An exception was made for the third question: if students had trouble coming up with ways they influenced the class, specific scenarios would be asked about, e.g., doing practical assignments, making posters, or working together.

Pre- and post-test (Second sub-question)

The pre- and post-test consisted of the SRQ-A questionnaire (Sierens & Vansteenkiste, 2009) altered for the subject of physics and administered anonymously. The exact questions can be seen in Appendix I. For both the pre- and the post-test, the questionnaire was the same.

Data analysis

Design focus group (First sub-question)

The focus group was transcribed and then coded. For the coding, a bottom-up approach was used, since the students gave very concrete examples and quotes, for which general design parameters were then found. The code book can be found in Appendix II.
A second coder was in near perfect agreement (Cohen's Kappa: 0.88).

Pre- and post-test (Second sub-question)

The SRQ-A questions each belong to their own category of motivation, which can be seen in Appendix III. Each question was ranked from 1 to 5, so the maximum score for each category is 20 and the minimum is 4. The RAI was then calculated by using *equation 1*.

The majority of post-tests was matched to a corresponding pre-test, and for those students the difference in motivational profile could be investigated. The gain, increase of the RAI after the intervention, could be calculated as follows:

Equation 2: Gain calculation

$$Gain = RAIpost\text{-}test - RAIpre\text{-}test$$

The gains could then be compared between groups using an independent t-test.

Second Focus Groups (Third sub-question)

For the coding of the transcripts for the second focus groups a top-down approach was used, based on the perceived feelings of support, or lack thereof, of the basic psychological needs (Reijerkerk, 2020; Shelton-Strong, 2020). To ensure a more unbiased look at the focus group and their statements, an independent researcher was second coder to the transcriptions (Cohen's Kappa: 0.923, indicating a near-perfect agreement). The code book can be found in *table 3*.

Code Book

Table 3: The code book as used for coding the second focus groups

Code	Name	Description	Example Quote
C+	Competence Supporting	Quotes showing a perceived positive competence: students felt they were capable of doing the tasks assigned, the subject was not too difficult, or they did not have troubles remembering or applying the concepts.	*"I just didn't think it was very difficult, the topics we got."*
C-	Competence Thwarting	Quotes showing a perceived negative competence: students felt they were not capable of doing the tasks assigned, the subject was either too difficult or too easy, or they had trouble remembering or applying the concepts.	*"[I thought it was] way too difficult."*
A+	Autonomy Supporting	Quotes showing a perceived positive autonomy: students felt they had a say in what they did (either during an activity or in deciding what activity to do), or they were allowed to make choices.	*"Because you are a bit more free [during experiments and making posters], you learn more from it."*
A-	Autonomy Thwarting	Quotes showing a perceived negative autonomy: students felt they had no say in what they did during class, or were not allowed to make any choices.	*"If I have influence on the lesson? Oh… no, not necessarily."*
R+	Relatedness Thwarting	Quotes showing a perceived positive relationship: students felt connected (to other students or a teacher), or could work together.	*"It's bothersome to [the rest of your group] if you are not doing anything, for example. Then you think 'I should really do something now'. If you are working on your own, then it is your own problem, but now you are also responsible for other people's exercises and then it's not fun if you don't do anything."*

Code	Name	Description	Example Quote
R-	Relatedness Supporting	Quotes showing a perceived negative relationship: students felt they had to do everything alone, or were not allowed to work together.	*"The people who understand [the exercise/the topic]... they don't understand that you don't understand."*
O	Other	Any quotes interesting to the research that do not fit into above-mentioned categories, or quotes relating to a different chapter than that of Energy.	*"I also know: I will never use it after this school year, so then I am not trying by best."*

Intervention

The intervention spanned one full chapter on the subject of "energy" and had the following structure:

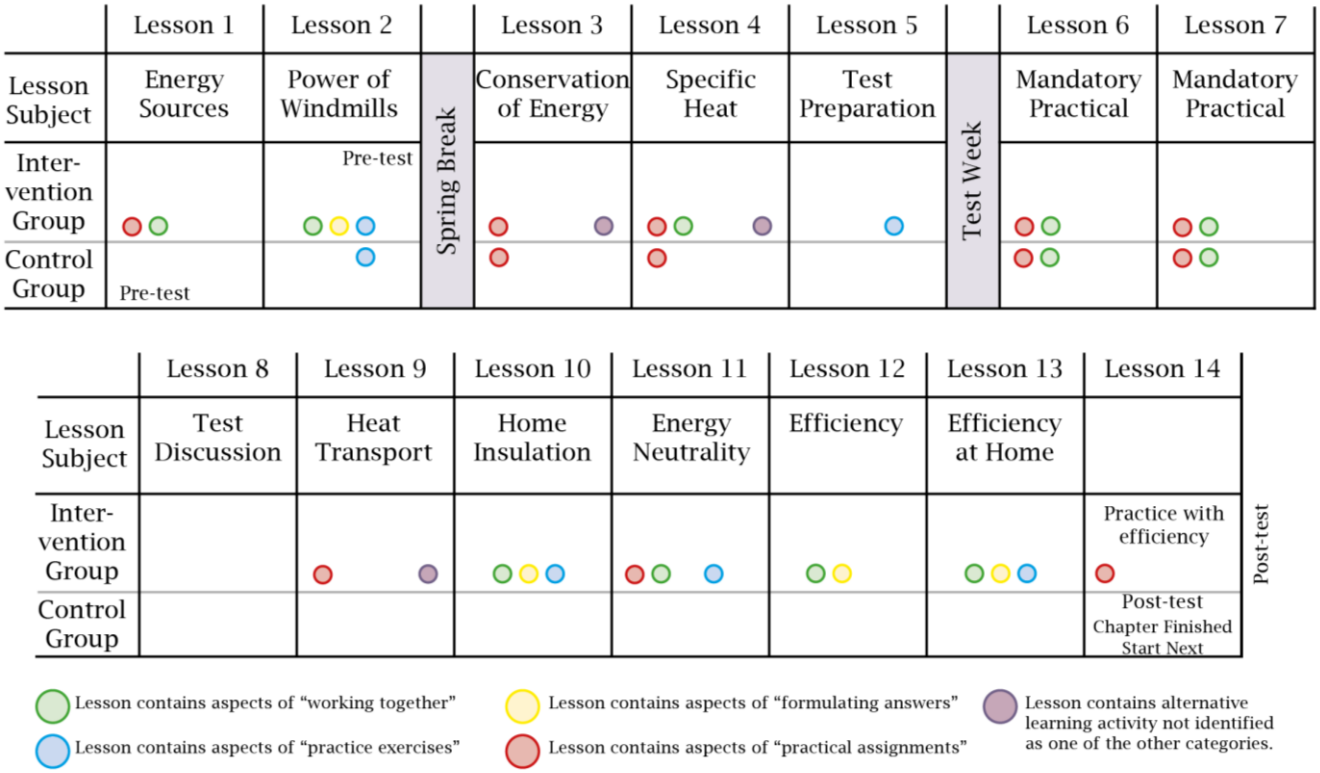

Figure 4: a visual representation of the activities done in each lesson of the lesson series for both the Intervention Group and Control Group

The colors in the lesson scheme represent the different design parameters as acquired from the design focus group, see the corresponding part in the Results section of this report. The "alternative learning activities not defined by other categories", color purple in *figure 4*, were activities such as Inquiry Based Learning, which relies heavily on the concepts of competence and autonomy and is therefore an activity that already satisfies the basic psychological needs. (Scott & Friesen, 2013). This intervention used activities such as having students make up an instruction to a practical, through figuring out how to get the required result from just the materials present.

Many activities required for students to work in groups. During lesson 1 through 7 of the intervention were either randomly generated or chosen by the students. From lesson 8 onwards, these groups were put together by the teacher. This was done because of the outcome of the design questionnaire: students indicated wanting to work with someone who was good at physics, and students who were going to choose physics indicated wanting to help people who were not as good at physics. To satisfy this, the teacher made sure the groups contained students with different levels of skill at physics.
Furthermore, the practice exercises also included a couple of example solutions, in order to make the students feel more competent at doing the exercises.

Results

Since many results were obtained using different instruments, the results section will be ordered using the sub-questions.
First, the results to the design questionnaire and the design focus group are presented, to answer the first sub-question. Then, to answer the second sub-question, the results to the pre- and post-tests (SRQ-A) are presented. Lastly, the results to the second focus groups are shown, answering the third sub-question.

Design Questionnaire (First sub-question)

For every question in the design questionnaire, the answers of the students indicating they were not going to choose physics were compared to the answers of the other students.

This indicated a couple of things, with all of the following having a significant difference between the non-choosers and the rest. (Appendix IV)

1. Non-choosers rated themselves as worse at physics than the others.
2. Non-choosers indicated that the pace of the physics lessons was too fast more than the others did. The others also indicating a high speed, but were more neutral.
3. Non-choosers did not agree the exercises in the book were too difficult, whereas the others were more neutral about that statement.
4. Non-choosers were on the disagree side of neutral when asked about liking to help others, whereas the others were had a slight tendency to agree.
5. Non-choosers were neutral about practical assignments being fun, whereas the others agreed practicals were fun.

Things both groups agreed on:

1. Both groups wanted to do more practical assignments.
2. Both groups prefer working together.
3. Both groups would like to work with someone who is good at physics.

The answers to the open question asked for a better direct instruction and the use of PowerPoint presentations, which were mentioned often and by both groups, and a need for practice exercises, which was more often mentioned by the “other” group.

Based on these results, questions were formulated for the design focus group:

1. What do you think about physics?
2. What do you think of an instruction using Power Point?
3. In what way would you like to work together during physics lessons?
4. What do you think of practical assignments in physics?
5. What else would help you with studying physics?

Follow-up questions were kept to a minimum, only asking for clarification or examples.

Design Focus Group (First sub-question)

The design focus group resulted in four design parameters to implement in the design. Students wanted:

- To work together.
- Practice exercises to match the level of the test.
- To do more practical assignments.
- To be better prepared on how to answer questions on a test.

Based on these design parameters, the conjecture map from *figure* 2 could be completed to look like this:

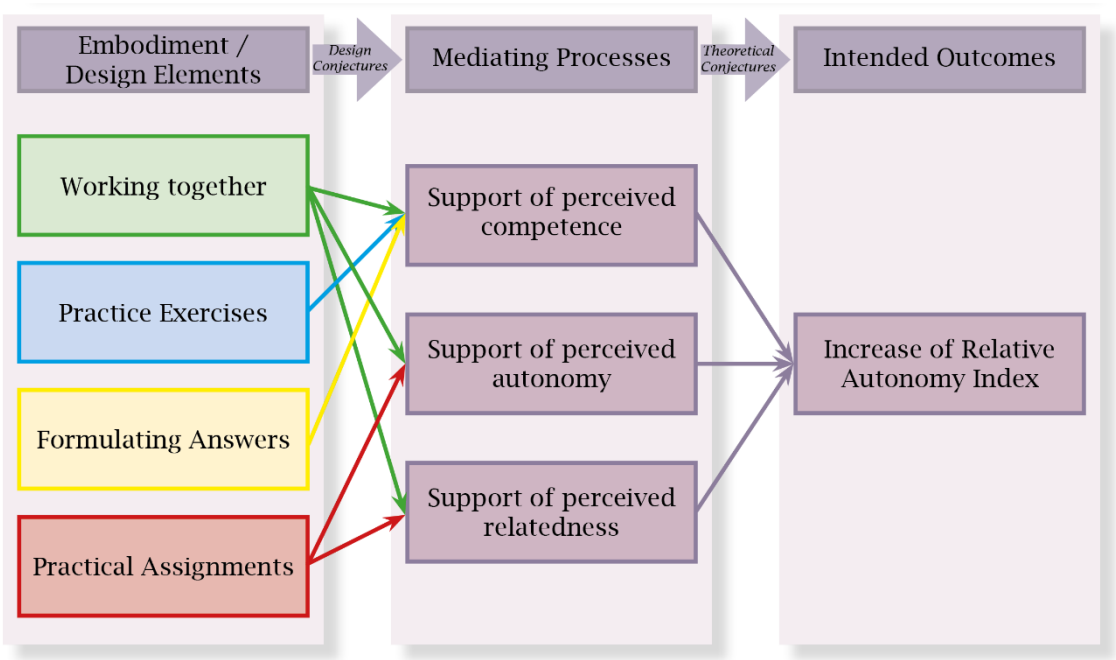

Figure 5: The completed conjecture map as used in this research. The represented Design Elements were found through the design questionnaire and design focus group.

Pre- and Post-Tests (Second sub-question)

RAI

The Relative Autonomy Indexes calculated using *equation 1* are shown in *table 4*:

Table 4: Means for the calculated RAIs for both the Intervention and Control Group for the pre-test and post-test.

	Group size	Pre-test RAI		Post-test RAI	
		Mean	Std. Dev.	Mean	Std. Dev.
Intervention Group	23	-4.91	12.303	-5.43	14.324
Control Group	22	11.23	14.787	5.18	15.218

Before the intervention, the RAIs for the Intervention Group were significantly lower than those for the Control Group, $t(43)=-3.988$, $p < .001$. (*Figure 6*)

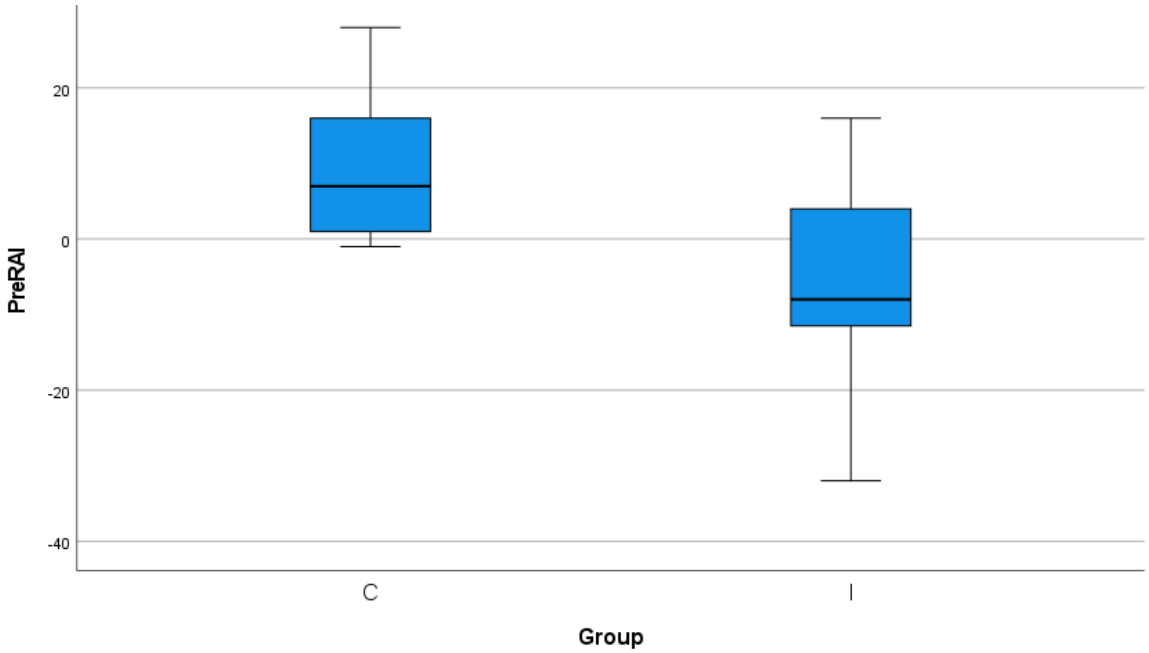

Figure 6: Boxplot for the pre-test RAI scores of the Control Group (C, on the left) and the Intervention Group (I, on the right)

After the intervention, the Control Group still had a significantly higher mean RAI than the Intervention Group, $t(43)=-2.411$, $p < .05$. (*Figure 7*) However, the distributions did get closer together. This can also be seen in the boxplot for the RAIs calculated from the post-test. The Intervention Group stayed around the same value, but the Control Group decreased.

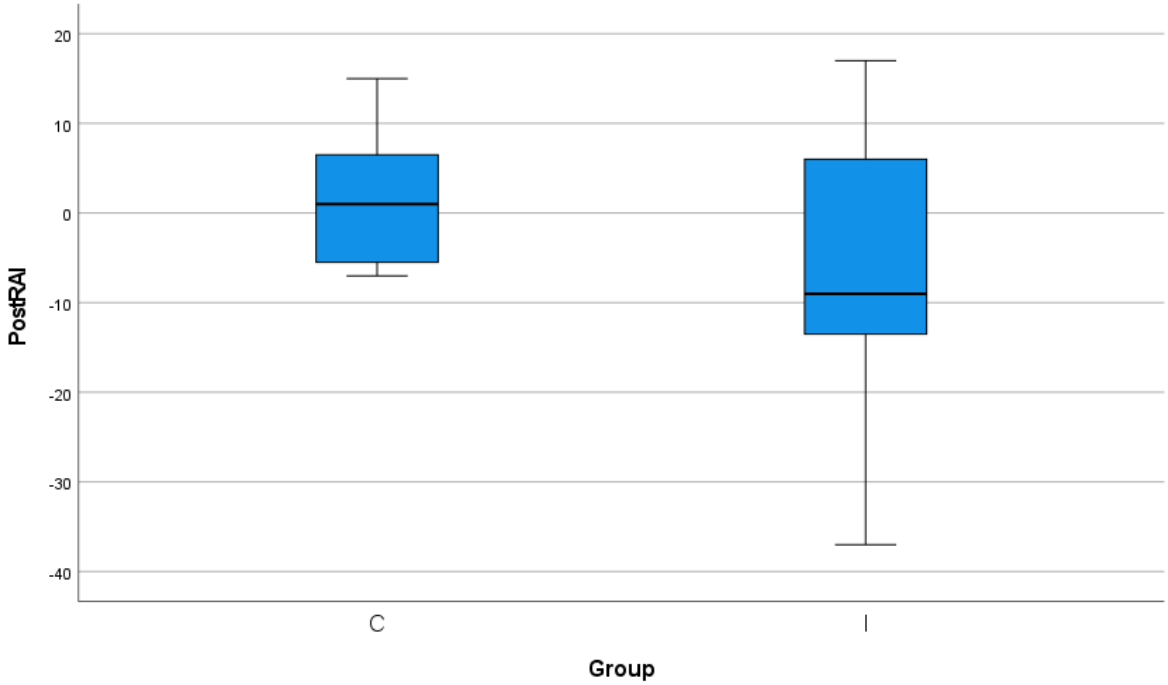

Figure 7: Boxplot for the post-test RAI scores of the Control Group (C, on the left) and the Intervention Group (I, on the right)

Gains

The Gain of the RAI was calculated for both groups, using *equation 2.* Note that not for all students the pre- and post-tests could be coupled, especially in the Control Group.

Table 5: Group sizes and corresponding means to the gains of the matching pre- and post-tests in the Intervention Group and Control group.

	Group size	Gains	
		Mean	Std. Dev.
Intervention Group	19	-0.2632	5.67492
Control Group	7	-8.1429	9.17294

The difference between these gains is significant, $t(24)=2.651$, $p < .05$, which means the Control Group had a significantly larger decrease in their RAIs. (*Figure 8*) The distribution of the gains looked as follows:

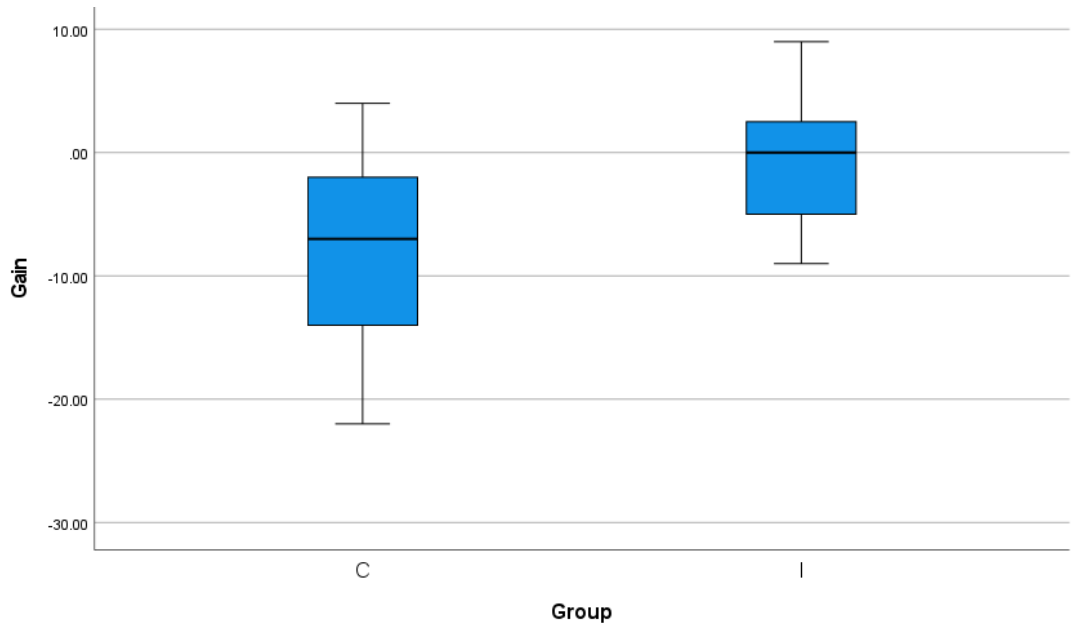

Figure 8: Boxplot for the Gains of the Control Group (C, on the left) and the Intervention Group (I, on the right)

Focus Groups (Third sub-question)

The frequency of quotes coded to each of the code book categories, as seen in *figure 3*, is shown in *figure 9*:

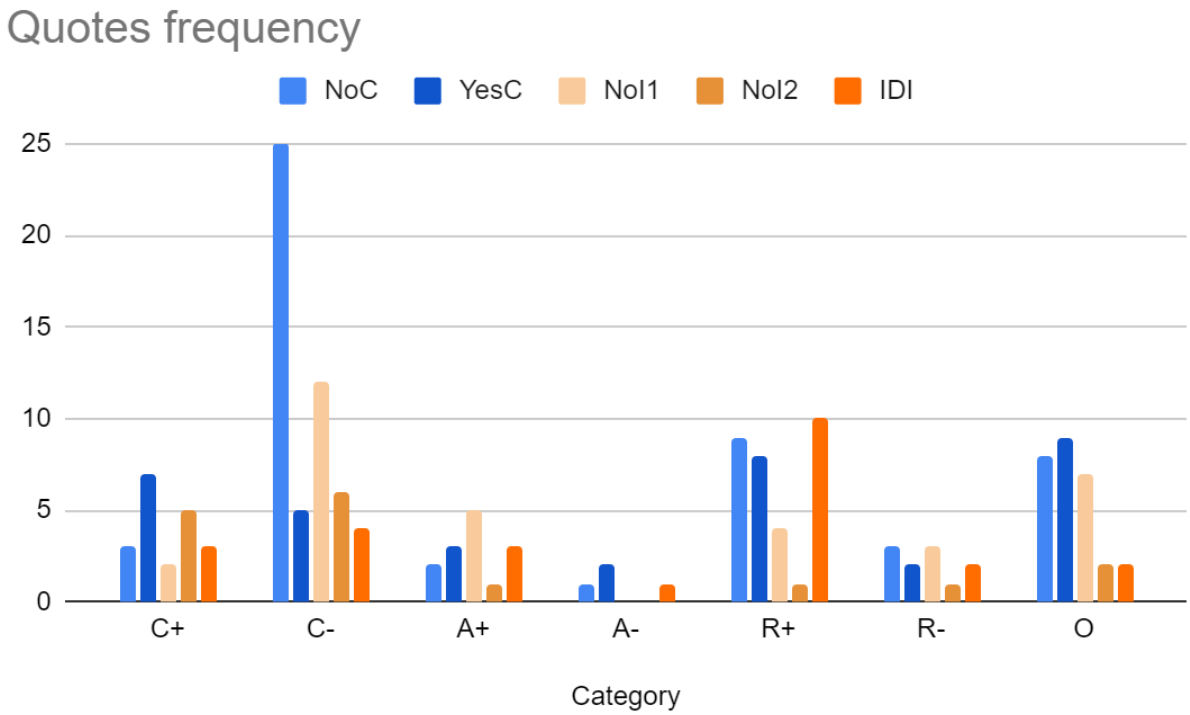

Figure 9: The frequency with which every category in the code book was mentioned by each focus group.

The total amount of quotes differs per focus group, which can be seen in *table 6*:

Table 6: The frequency each category of quotes was mentioned by each focus group, also including the total amount of quotes from that group.

	Focus groups: amount of quotes from group				
Category	NoC	YesC	NoI1	NoI2	IDI
C+	3	7	2	5	3
C-	25	5	12	6	4
A+	2	3	5	1	3
A-	1	2	0	0	1
R+	9	8	4	1	10
R-	3	2	3	1	2
O	8	9	7	2	2
Total	51	36	33	16	25

Competence Thwarting (C-)

The most apparent feature in *figure 9* is the large number of C- quotes from NoC. Those quotes concern different issues the students experience: using formulas, time-related issues, and learning activities.

Formulas

Formulas seemed to be a big inconvenience for all non-chooser groups. This accounts for 7 out of 25 quotes NoC has in this category.

> *[1] NoC: "Then you kind of know what the formula is, but how to use it? I don't know that."*

> *[2] NoC: "I especially think it's difficult [if] you have to use multiple formulas. That you don't know which one."*

Such quotes on formulas were also seen in NoI1 (4 out of 12) and NoI2 (2 out of 6). No quotes on formulas were given in YesC and IDI.

Time-related issues

Another big issue for NoC was the fact that during the lesson there was not enough time to understand and grasp the subject. They made six remarks on that.

> *[3] NoC: "[The teacher] does a lot of example exercises during the lesson, but if you already don't understand one of them, the you usually do not understand the next one either."*

> *[4] NoC: "Maybe we are going a bit too fast [during class]."*

Especially *quote 4* is interesting, since the YesC group thought the examples were quite slow. The speed of the lesson is perceived differently by the different sub-groups in one class.

> *[5] YesC: "Then, for example, we got an example exercise and then [the teacher] explained it for the whole lesson and at the end of the lesson all you've done is that example exercise."*

The only other group to mention a difficulty in matching the speed was IDI (1 out of 4 quotes). Neither NoI1 nor NoI2 mentioned speed of understanding during the focus groups.

Learning Activities

Compared to the Control Group, there was one aspect of competence that the Intervention Group could only comment on: the learning activities. The C- quotes in the Intervention Groups focused more on the alternative learning activities they did. NoI1 had 2 out of 12 quotes about this, and NoI2 4 out of 6:

> *[6] NoI2: "Sometimes with the poster exercises you didn't really know what to do. The exercises were unclear sometimes. What were we to do?"*

> *[7] NoI1: "If you had to explain to other people how you did the [group] exercises, you didn't even know how you yourself did them. Then you can't explain it to others."*

IDI however, expressed feeling supported competence due to the learning activities:

> *[8] IDI: "I feel like I do more with exercises like [the posters]. And practical exercises. I feel like I do and understand more."*

Autonomy Supporting (A+)

Autonomy is felt differently by the Intervention Group than by the Control Group, namely through learning activities, or teacher behavior.

Learning Activities

The Intervention Group focused their feelings of autonomy on the learning activities they did. They felt supported in their autonomy by the choices they made during the activities in class. NoI1 mentioned this in 2 of 5 quotes on autonomy, NoI2 had just one quote on autonomy which falls into this category, and IDI mentioned this in 2 out of 3 quotes.

> *[9] NoI1: "Because [during the posters and experiments] you're a bit more free, you also learn more from it."*

YesC and NoC did not mention feeling free during the activities they did in class. On the contrary, they mention a lack thereof.

> *[10] YesC: "I just mainly feel like we are busy with the instruction and then we make exercises and that was the lesson."*

Teacher Behavior

The Control Groups felt autonomy through behavior their teacher exhibited: adhering to requests the Control Group made. YesC mentioned supported autonomy through their teacher in 1 out of 3 A+ quotes, and NoC mentioned it in both A+ categorized quotes.

> *[11] NoC: "I once told [the teacher] that 'maybe it would be nice if you used PowerPoint.'"*

NoI1 also expressed autonomy due to asking the teacher (2 out of 5 quotes):

> *[12] NoI1: "At some point we got [the teacher] to use PowerPoint presentations."*

Moreover, this specific quote indicates an influence from the design focus groups on the motivational profile of the Intervention Group, but this is further explored in the Discussion section.

Relatedness Supporting (R+)

Another big difference between the Intervention Groups and the Control Groups is how they perceived a supported need for relatedness. This need is satisfied differently for both groups: amongst students themselves during learning activities, or specifically with the teacher.

Learning Activities

The NoI1 and NoI2 group expressed less feelings of supported relatedness compared to the other groups. The things NoI1 expressed, related to the learning activities (3 out of 4 quotes).

[13] NoI1: "If you are [in a group] with people who understand [the subject] a little, then eventually you'll figure it out together."

IDI expressed positive relation due to the learning activities in 8 of 10 quotes categorized in relatedness supporting.

[14] IDI: "Also with the posters, I liked it. You could discuss more with each other, about what they think and what you yourself think and then you come to a conclusion."

Teacher Behavior

The Control Groups have done less group activities during the intervention, and therefore expressed little support from other class members. The supported relatedness they felt was mainly due to the relationship they had with their teacher. YesC and NoC expressed six quotes each on this supported relatedness due to the teacher (out of 8 and 9 respectively).

[15] YesC: "[The teacher] really tries his best."

[16] YesC: "But I just always think it's nice with him, because you can just raise your hand and he'll be with you to explain as soon as he can, so that is nice."

Other (O)

The quotes in this category were quotes that do not fit into one category, but are relevant to the situation. These quotes relate to motivation, either through learning activities or directly mentioning motivation, but students do not (indirectly) refer to one of the basic psychological needs.

Learning Activities

Some quotes directly refer to students enjoying learning activities, indicating intrinsic motivation, with four such quotes out of 9 in the YesC, and one out of 8 in NoC.

[17] YesC: "I just think it's nice if we do more practical exercises."

In such quotes, they don't explain why it was fun or interesting, but they do show appreciation for having done such exercises, or wishing to do more. Both IDI (2 out of 2) and NoI1 (1 out of 7) mentioned such learning activities as well, but there were no wishes to do more. These quotes were mainly focused on having done these activities.

[18] NoI1: It's nice [to make posters] in between all of those… boring lessons."

[19] IDI: "I actually thought it was nice that we had variety between making the posters and… being busy and the presentations you gave during class."

Talk about Motivation

Students also mentioned motivation in general, either their own or observed motivation in classmates. The majority of the quotes related to a, in students' words, "lack" of motivation, indicating amotivation or a heavily controlled motivation. Especially the Control Groups saw such quotes, with YesC having 3 out of 9 quotes related to this, and NoC 7 out of 8.

[20] NoC: "I also know: I am never going to use it anymore after this school year, so I am not really going to do my best."

Of the Intervention Groups, only NoI1 saw 2 such quotes out of 7. NoI2 and IDI did not mention overall motivation.

Conclusions

First Sub-question

According to students, what are candidate elements of a physics lesson series that support the basic psychological needs of students?

According to the answers gathered from the design questionnaire distributed amongst five 9th grade classes of pre-university secondary education and the follow up design focus group in which four students of the Intervention Group participated, four elements student want in a physics lesson series were acquired. These elements are working together, doing practical assignments, having practice exercises at test level available, and learning how to study for a test and formulate answers to physics questions. The element present throughout is that of presentational guidelines. The presentation helps students focus on the instruction, and should therefore be present during a classical part of a lesson.

Second Sub-question

To what extent does an environment that support the basic psychological needs influence the motivational profile of students during a physics lesson series?

Even after the intervention, the Control Group remains at a significantly higher average RAI than the Intervention Group. However, the effect of the intervention could be seen from the Gains: those indicate that students in the Intervention Group remained at the same level of autonomous motivation, while the students in the Control Group had a significantly more decreased autonomous. The fact that their RAI was still significantly higher post-intervention, probably partly has to do with the fact that the Control Group has thrice as many students wanting to choose physics in their subject cluster choice and therefore likely being more motivated to do physics on their own.

Thus, the intervention helped keep the RAI stable, even for a group that largely consisted of students who were not going to choose physics.

Third Sub-question

What do the students report on the support of their basic psychological needs by the different elements of the lesson series?

In both the Intervention Group and Control Group, students who were not choosing physics, and might therefore be less skilled at physics, reported having trouble with the formulas they get confronted with during class. Both groups might need to be trained to deal with difficult formulas more, although it seems a more pressing matter for the Control Group, as they reported more on time-related issues, e.g., situations in which the example exercises went too quickly and took too long to comprehend. The Intervention Group barely mentioned such issues and was more concerned with the learning activities and their perceived competence in that regard, which might have resulted in them reporting less on the pace of the lesson series.

The learning activities also supported the students in the other two basic psychological needs: by having students work together and give them autonomy within learning activities. Students reported on support in both categories. Thus, learning activities made it so the students did not have to rely on other, more circumstantial, sources of support for their basic psychological needs, such as teacher behavior.

Overall, students in the Intervention Group reported having been glad to have done learning activities and the students in the Control Group reported wishing they did such activities more often. Although the learning activities employed in this study cannot support the basic psychological needs at all levels and all aspects, they did support the students in all three basic psychological needs at some level.

Main Research Question

The main research question can now be revisited:

What elements of a physics lesson series support the basic psychological needs for students who have not chosen physics in their subject cluster choice?

In order to support the basic psychological needs for students during a physics lesson, the following things need to be done:

- Let students work together. Letting students choose their own groups to work in supports their autonomy, while having them paired with respect to ability will affect the supported feeling of relatedness.

- Do more practical assignments. Students reported learning more due to a higher perceived autonomy.

- Have students do practice exercises at the test level. If done in groups to discuss, this will help in the feeling of competence toward the test.

- Help students to study for the test by doing learning activities targeted at formulating answers, in order to combat the feeling of having studied a lot without a positive result.

Doing learning activities that fall into these categories makes students feel supported in their basic psychological needs. As a result, they won't have to rely solely on other sources of support that may be circumstantial, such as teacher behavior.

By implementing these aspects in a lesson series, students will remain feeling the same levels of autonomous motivation, regardless of whether they choose physics in their subject cluster choice.

Discussion

Limitations

The main limiting factor encountered in this research is that of relatively small group sizes. The Intervention and Control Group each contained just 24 students. Ideally, there would have been more groups subjected to the intervention and more groups to gather data from, but due to practicalities, this was not possible. Due to both the Intervention Group and Control Group needing to receive the same kind of education, the bilingual classes were only included in the design questionnaire.
A bigger issue was the fact that matching the results from the post-test to the corresponding pre-test was quite hard to do. This was seen especially in the Control Group. Due to the long duration of the intervention, students may have forgotten their personal codes.
However, despite the small data-set, the results were significant. This won't change the main take-away from this report, but a larger amount of match-ups would have allowed for in-group comparisons, taking into account more the difference between non-choosers and other students, and not only the Intervention and Control group in general.

A second limiting factor was the fact that both classes were taught by a different teacher, again, due to practicalities. Both teachers had quite a different teaching style, resulting in inherently different feelings of support in the basic psychological needs. The effect of having a different teacher cannot be easily distinguished.

A further limitation may lie in the fact that the design focus group was held in the same group as the Intervention Group. Originally, the design focus group was to be held in an independent group, but due to last-minute difficulties and adaptations, this became Intervention Group in order to still be able to properly conduct the research.
One possible influence of the Design Focus Group on the motivational profile, lay in the students requesting PowerPoint presentations during the focus group. The students who specifically requested that, might therefore have already felt supported in their basic psychological needs just from having that request granted. However, as shown in the Results section, this request was not limited only to the Intervention Group. Both classes had asked for PowerPoint presentations, which makes any supported feeling of basic psychological needs due to the PowerPoint presentations the same for both groups, and can therefore be negated as a factor.

Limitations to the Design of the Intervention

Due to the spring break and test week, the intervention had to cover certain parts of the chapter before the test week, because the students needed to be properly prepared.
The second limiting factor is a mandatory practical assignment, which takes up two lessons in the lesson series and because it was mandatory, there was no difference between the Control Group and the Intervention Group.

Moreover, the Control Group ended up doing a practical assignment in the lesson after the post-test. This didn't end up being a factor in the post-test, but it was mentioned in the second focus groups, which made it possible to take the effect of that un-planned similarity between the Control Group and the Intervention Group into account.

Implications

Despite the limitations, significant results were found. This implies that in order to keep students' motivation consistent, they just need to be listened to.
In this study, that was done by directly implementing the design parameters the Intervention Group themselves stated they wanted. By letting them work together in the ways they described during the design focus group, by giving them PowerPoint presentations to rely on during direct instruction, by giving them exercises at the level of the test, by letting them reflect on how to answer physics problems, and by allowing them to use their hands more often in creative and physical assignments, the students felt supported in each of the basic psychological needs. Although the intervention did not remove every problem they had with physics, their RAI remained stable due to having someone listen to what they wanted from the physics lesson, within the boundaries of the curriculum.

Future Research

The design parameters found in this research were specific to this group and this situation. It would therefore be interesting to further investigate the effect including these parameters into your lesson series has on the motivational profile of students in similar groups. First, with 9th graders in the Netherlands, but it would also be interesting to see the effect they have on students of the same age in different countries.

Furthermore, it would be interesting to learn the effect these design parameters have on the motivational profile of students who have actually chosen physics. In the Netherlands, that would mean 10th grade students or higher. It is possible that including the design parameters in lesson series targeted at them will make them even more autonomously motivated.

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Appendix I: SRQ-A Altered for Physics

Table 7: The questions and answer options of the pre- and post-test. These questions are the same as those in the SRQ-A questionnaire, but altered for the subject of physics.

Question/Statement	Answer
Will you choose physics in your subject cluster choice?	"Yes", "No", "Don't know yet"
I am motivated for the subject physics because I think physics is interesting.	Students were asked to rank how much they agreed with the statements: I disagree I slightly disagree Neutral I slightly agree I agree
I am motivated for the subject physics because physics is fun.	
I am motivated for the subject physics because I think physics is fascinating.	
I am motivated for the subject physics because I think studying for physics is a pleasant activity.	
I am motivated for the subject physics because I want to learn new things about physics.	
I am motivated for the subject physics because I think physics has a lot of value.	
I am motivated for the subject physics because it is very important for me personally to learn about physics.	
I am motivated for the subject physics because I think this is an important life goal.	
I am motivated for the subject physics because I want others to think I am wise.	
I am motivated for the subject physics because I would feel guilty if I would not work for it.	
I am motivated for the subject physics because I would feel ashamed if I would not work for it.	
I am motivated for the subject physics because I want to give others the impression that I am a good student.	
I am motivated for the subject physics because I am supposed to take the subject.	
I am motivated for the subject physics because others (parents, friends, teachers,…) force me to work for it.	
I am motivated for the subject physics because others (parents, friends, teachers,…) oblige me to work for it.	
I am motivated for the subject physics because others (parents, friends, teachers,…) expect me to work for it.	

Appendix II: Code book to the Design Focus Group

Table 8: Code book and frequencies of quote categories to the Design Focus Group

Category	Category definition	Example quote (translated to English)	Number of quotes in category
Practice exercises	Quotes relating to why practice exercises are useful and how they could be facilitated.	*"[When you have a practice test] you kind of know what will be on the test."*	4
Studying for the test	Quotes relating to how students study for the test.	*"I usually read the text [in the book] and the PowerPoint, but then I make all the exercises."*	5
Presentation guidelines	Quotes relating to aspects of a presentation that accompanies an instructional part of the class.	*"If you are distracted and you look back [at the PowerPoint], you still know what the instruction is about."*	4
Working together	Quotes relating to how working with peers positively affects the students' work and how it can be facilitated.	*"If, for example, you have a few exercises, you can make them together. You will understand it better then. When you don't understand a certain part, someone else will."*	4
Practical exercises	Quotes relating to how practical assignments help motivation and understanding.	*"During the test you can think back at what you did [during the practical exercise]."*	4

Appendix III: The SRQ-A Categories for Calculating the RAI

Table 9: The questions of the SRQ-A questionnaire and their corresponding category of which kind of motivation they measure.

Kind of motivation	Questions in that category
Intrinsic	I am motivated for the subject physics because I think physics is interesting.
	I am motivated for the subject physics because physics is fun.
	I am motivated for the subject physics because I think physics is fascinating.
	I am motivated for the subject physics because I think studying for physics is a pleasant activity.
Identified	I am motivated for the subject physics because I want to learn new things about physics.
	I am motivated for the subject physics because I think physics has a lot of value.
	I am motivated for the subject physics because it is very important for me personally to learn about physics.
	I am motivated for the subject physics because I think this is an important life goal.
Introjected	I am motivated for the subject physics because I want others to think I am wise.
	I am motivated for the subject physics because I would feel guilty if I would not work for it.
	I am motivated for the subject physics because I would feel ashamed if I would not work for it.
	I am motivated for the subject physics because I want to give others the impression that I am a good student.
Extrinsic	I am motivated for the subject physics because I am supposed to take the subject.
	I am motivated for the subject physics because others (parents, friends, teachers,…) force me to work for it.
	I am motivated for the subject physics because others (parents, friends, teachers,…) oblige me to work for it.
	I am motivated for the subject physics because others (parents, friends, teachers,…) expect me to work for it.

Appendix IV: Means and p-test values for the design questionnaire responses

Answer options:

1. Disagree
2. Slightly disagree
3. Neutral
4. Slightly agree
5. Agree

Table 10: Means, standard deviations and p-values for the independent t-tests for the answers to the orientational questionnaire between the students who are going to choose physics in their subject cluster choice and those who will not.

	Mean non-choosers	Std non-choosers	Mean others	Std others	Test results statistics
"I am good at physics."	2.05	1.284	3.08	0.889	$t(84)=-4.111$, $p < .001$
"I feel like we move through the topics too fast."	4.19	0.981	3.45	1.046	$t(84)=2.876$, $p = .005$
"I think the exercises in the physics lesson book are too easy."	1.81	1.123	2.54	0.953	$t(84)=-2.915$, $p = .005$
"I think practical assignments in physics are fun."	3.05	1.359	3.69	1.074	$t(84)=-2.236$, $p = .028$
"I would like to more often do practical assignments during physics lessons."	4.05	1.284	3.97	0.951	$t(84)=.300$, $p = .765$
"I prefer working on physics with other people."	4.33	1.065	4.18	0.900	$t(84)=.629$, $p = .531$
"I like working with a classmate who is good at physics.	4.00	0.775	4.02	0.960	$t(84)=-.067$, $p = .947$
"I like to help out fellow classmates who are less skilled at physics than I am."	2.71	1.488	3.37	0.911	$t(84)=-2.423$, $p = .018$

Appendix V: Cronbach's Alpha for Pre-tests and Post-tests

Table 11: Chronbach's Alpha for each category of the pre-test and the post-test for both the Intervention Group and Control Group.

	Pre-test		Post-test	
	Category	Cronbach's Alpha	Category	Cronbach's Alpha
Intervention Group	Intrinsic	0,921	Intrinsic	0,881
	Identified	0,819	Identified	0,878
	Introjected	0,735	Introjected	0,769
	Extrinsic	0,895	Extrinsic	0,893
Control Group	Intrinsic	0,948	Intrinsic	0,936
	Identified	0,921	Identified	0,933
	Introjected	0,864	Introjected	0,862
	Extrinsic	0,805	Extrinsic	0,790

Appendix VI: Normality of the Gains

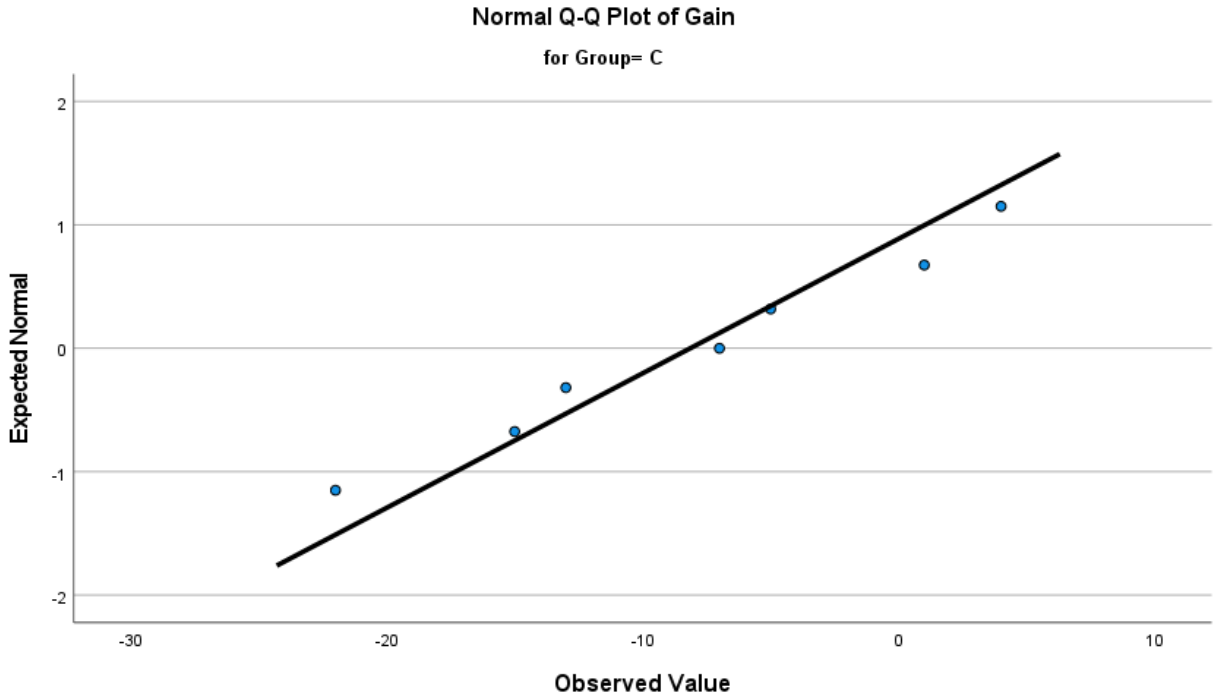

Figure 10: The normality Q-Q Plot of the Gains in the Control Group

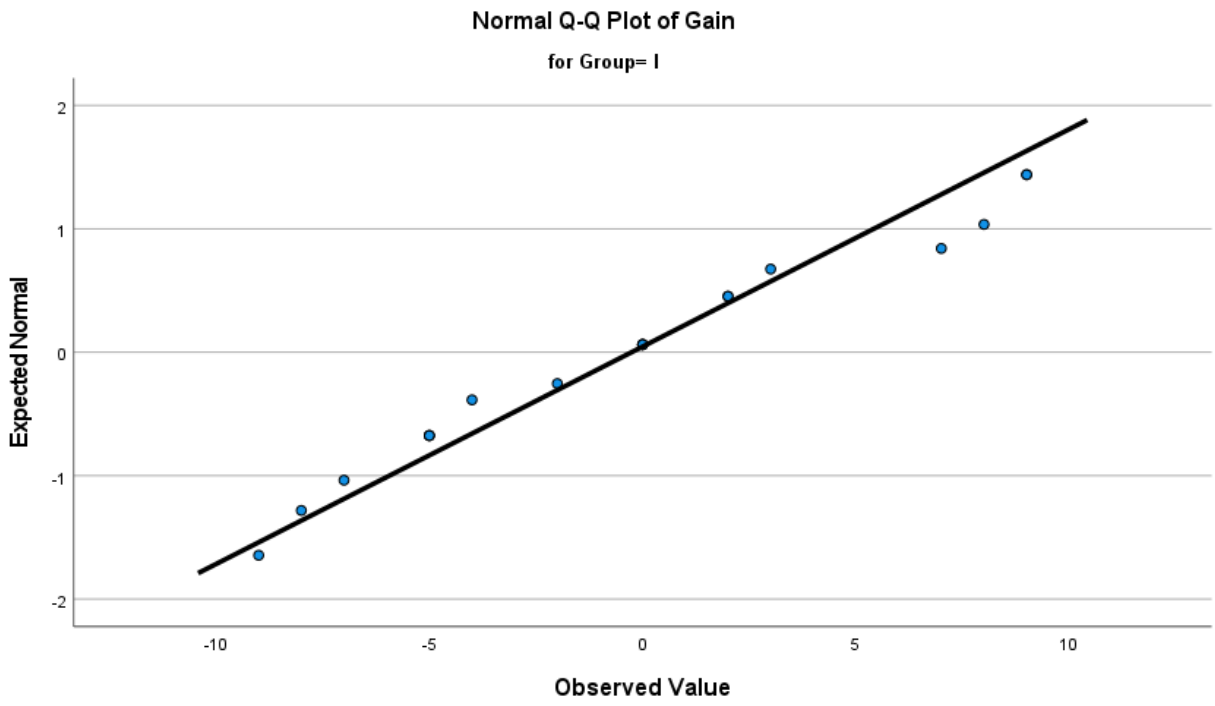

Figure 11: The normality Q-Q Plot of the Gains in the Intervention Group

Appendix VII: Original Versions of the Used Quotes

Competence Thwarting (C-)

Formulas

1. “Dan weet je wel een beetje wat de formule is, maar hoe moet je het gebruiken? Dat weet ik niet.”

2. “Ik vind het vooral moeilijk [als] je, zeg maar, meerdere formules moet gebruiken. Dat je dan niet weet welke.”

Time-related Issues

3. “[De docent] doet wel heel veel voorbeelden in de les, maar als je al één voorbeeld ervan niet snapt, dan snap je meestal de volgende ook dan weer niet.”

4. “Misschien dat we toch een beetje snel gaan [tijdens de les].”

5. “Dan kregen we bijvoorbeeld een voorbeeldopgave en dan legde [de docent] daar de hele les over uit en dan heb je aan het eind van de les alleen die voorbeeldopgave gedaan.”

Learning Activities

6. “Af en toe met die posters dan wist je niet precies wat je moest gaan doen, enzo. En soms waren de opdrachten ook een beetje onduidelijk. Wat moet je nou doen?”

7. “Als jij dan aan andere mensen uit moet gaan leggen hoe jij je opdracht [in groepjes] hebt gemaakt, dan weet je niet echt hoe je het zelf überhaupt hebt gedaan. Dan kan je het niet aan andere mensen gaan uitgeleggen.”

8. “Ik heb ook het gevoel dat ik meer doe bij opdrachten zoals [de poster]. En [praktische opdrachten], zeg maar, heb ik het gevoel dat ik meer doe en meer begrijp.”

Autonomy Supporting (A+)

Learning Activities

9. “Omdat je [tijdens posters maken en experimenten] iets vrijer bent, dan leer je er ook meer van.”

10. “Ik heb gewoon vooral het idee dat we vooral bezig zijn met de uitleg en daarna opdrachten maken en dat was de les.”

Teacher Behavior

11. “Ik heb één keer tegen [de docent] gezegd van 'misschien is het fijner als je een Power Point gebruikt'.”

12. “Op een gegeven moment hebben we [de docent] zover gekregen dat u toch maar wel presentaties ging gebruiken.”

Relatedness Supporting (R+)

Learning Activities

13. “Als je met mensen [in het groepje] zit die [de stof] een beetje begrijpen, dan kom je er uiteindelijk samen wel uit.”

14. “Ook met die posters, vond ik ook wel leuk. Je kan meer met elkaar bespreken en discussiëren over wat zij vinden en wat je zelf vindt en kom je eigenlijk tot een conclusie uit.”

Teacher Behavior

15. “[De docent] doet wel z'n best.”

16. “Maar ik vind het wel altijd gewoon fijn bij hem, want je kan altijd gewoon je hand opsteken en hij komt ook zo snel mogelijk naar je toe en legt het uit, dus dat is wel fijn.”

Other (O)

Learning Activities

17. “Ik vind het gewoon fijn als we meer [praktische opdrachten] doen.”

18. “Toch wel fijn [om posters te maken] tussen al die… saaie lessen door.”

19. “Ik vond het wel eigenlijk fijn dat we de afwisseling tussen posters maken en, zeg maar, bezig zijn en van presentaties die u gaf tijdens de les.”

Talk about Motivation

20. “Ik weet ook: ik ga het nooit meer gebruiken na dit schooljaar, dus dan ga ik niet meer echt mijn best doen.”