Teachers' motivating style and students' motivation and engagement in STEM : the relationship between three key educational concepts

Teachers' motivating style and students' motivation and engagement in STEM: The relationship between three key educational concepts

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Abstract

A key theme in the science education literature concerns the reluctance of students to participate in Science, Technology, Engineering and Mathematics (STEM). Self-determination theory (SDT) states that social factors in an educational setting, such as teachers' motivating style, can influence students' motivation and engagement. This paper investigates the relationship between STEM-teachers' motivating style (autonomy support, provision of structure, involvement) and students' motivation and engagement with regard to STEM. Furthermore, the relationship between students' motivation and students' engagement is investigated. Thirty classroom observations were conducted in different STEM lessons, to assess teachers' motivating style and students' engagement. The students' motivation was assessed at the end of the school year, using an online questionnaire. The results reveal that STEM-teachers' provision of structure is positively linked to students' motivation and engagement with regard to STEM subjects. The impact of teachers' autonomy support was negatively predictive for students' autonomous motivation, and positively predictive for students' engagement. A negative relationship between students' controlled motivation and engagement was found. Based on these results, this study suggests that taking teachers' motivating style into account in future educational initiatives regarding STEM is highly relevant as a means of stimulating students' motivation and engagement.

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1. Introduction

A key theme in the science education literature is the increasing reluctance of students to participate in Science, Technology, Engineering and Mathematics (STEM) (Bøe, Henriksen, Lyons, & Schreiner, 2011; Pinxten et al., 2017). Especially in highly developed countries, students are disengaging from STEM subjects (OECD, 2008). This increasing unwillingness on the part of students to participate in STEM is a matter of concern for multiple reasons. Societies need qualified STEM professionals to meet contemporary demands, such as securing sufficient and sustainable energy, efficient healthcare and well-considered technological development (Bøe et al., 2011). Furthermore, all students need to have some understanding of the role of STEM in society (OECD, 2008). Compulsory education plays an important role in responding to these issues, as scientific career attainment is influenced by the early choices made by students (Lavigne, Vallerand, & Miquelon, 2007). Students who have a high quality of motivation, maintain their engagement as the years progress, whereas students who lack motivation tend to become more disengaged over time (Skinner, Furrer, Marchand, & Kindermann, 2008). In order to increase students' motivation and engagement in STEM, it is important to investigate which factors can foster these aspects in a STEM learning environment. In the current study, we focus on the role of STEM-teachers, and we will use the framework of self-determination theory (SDT) to study the relationship between teachers' motivating style and students' motivation and engagement. SDT is an established motivational theory that has proved its value in the educational field (De Naeghel, Van Keer, Vansteenkiste, & Rosseel, 2012).

1. 2. Basic psychological need support

SDT assumes that humans have three basic psychological needs: the need for autonomy, relatedness, and competence (Deci & Ryan, 2002). Importantly, SDT states that satisfaction of these three basic psychological needs will positively affect motivation and engagement. The social context can support or thwart individuals' basic psychological needs, and thus motivation and engagement. In the context of an educational setting or classroom, teachers have a crucial role to play (Wentzel, Muenks, McNeish, & Russell, 2017). Teachers can influence students' motivation and engagement through their *motivating style*, which refers to the degree a teacher supports the students' three basic psychological needs (Tessier, Sarrazin, & Ntoumanis, 2010). Teachers who fulfill these needs have a need supporting or motivating style, in contrast to teachers with a need frustrating motivating style, who tend to define what students should think, feel and do (Reeve, Jang, Carrell, Jeon, & Barch, 2004).

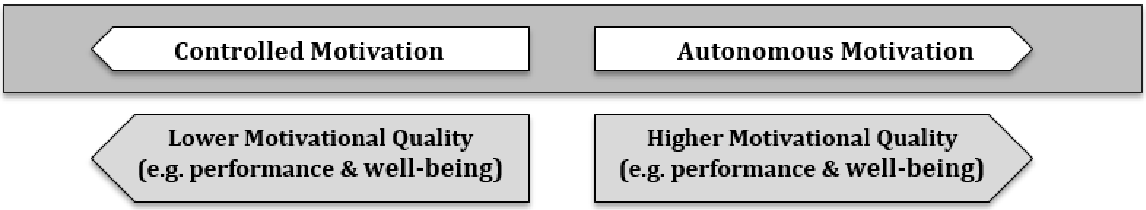
Autonomy refers to *"…being the perceived origin or source of one's own behavior"* (Deci & Ryan, 2002, p. 8). Applied in an educational context, students will experience autonomy when they perceive their engagement in learning as being their own choice, reflecting their own interests and values (Stroet, Opdenakker, & Minnaert, 2013). Importantly, autonomy is not the same as independence (which means not being influenced by outside sources). Regarding SDT, an individual can experience autonomy, even when actions are influenced by external sources (Deci & Ryan, 2002). Teachers can be autonomy supportive in various ways. Autonomy support consists of a number of different components. Teachers can support their students' autonomy by providing them with *choice.* This includes allowing their students – to a certain degree – freedom to choose tasks and subjects that they perceive as being interesting or important (Assor & Kaplan, 2001; Stroet et al., 2013). Also *fostering relevance* (e.g. by linking the learning content to students' everyday environment) and using *informational* (e.g. can, is possible) instead of *controlling language* (e.g. should, must, have to, got to) are acts of autonomy supportive behavior (Assor & Kaplan, 2001; Reeve et al., 2004).

Relatedness concerns feelings connected to, or having a, 'sense of belonging' towards other individuals or one's community (Deci & Ryan, 2002). Baumeister and Leary (1995) state that the need for relatedness or the need to belong has two main components. On the one hand, people need frequent conflict-free personal contact that is ideally affectively positive and satisfying. On the other hand, people need to perceive that their interpersonal relationships are marked by stability, emotional affection and continuation in the future. The need for relatedness can be fulfilled through interpersonal contact or by being integrated in a social group or community. Stroet et al. (2013) argue that within a (secondary) educational context, a teacher's relationship with students is not strong enough to satisfy the students' need for interpersonal relatedness. However, teachers can impact students' feelings of relatedness at school by their degree of *involvement* in the classroom. Relatedness is conceptualized as involvement in the relationship between the teacher and the student (Reeve et al., 2004; Tessier et al., 2010). Reeve et al. (2004) suggest that a teacher can express their involvement in the classroom by, for example, walking over to the students instead of staying up front during the class, expressing care, knowing students' names and investing time and energy.

Competence refers to the satisfaction that people derive from exercising and expressing their capacities (Ryan & Deci, 2002). For students, feelings of competence are enhanced if they obtain more control over school outcomes (Stroet et al., 2013). Teachers can support the basic psychological need for competence by *providing structure*. Structuring the learning environment is not equal to limiting students in the process of exploration or the expression of creativity. Stroet et al. (2013) distinguish four aspects of teachers' provision of structure based on the literature. First, providing *clarity* in terms of giving clear, detailed and understandable instructions. Second, providing students with *constructive and informational feedback.* Third, offering students *guidance* during their class activities by, for example, monitoring their work or offering help when needed can provide structure to students. Fourthly, teachers' *encouragement* can provide students with structure, consequently making students feel they have more control over school outcomes. Teachers can, for example, encourage students by expressing positive expectations with regard to school work.

1.2. Motivation and engagement

According to SDT, different types of *motivation* apply to individuals. Motivation can range on a continuum of 'amotivation' (no motivation towards an activity) to 'intrinsic motivation'. The latter is self-determined motivation, because an individual is motivated by the self, rather than by external factors such as pressure or rewards (Ryan & Deci, 2000a; Tessier et al., 2010). A student who is, for example, strongly interested in STEM and wants to understand the universe, is intrinsically motivated to put effort into STEM classes. In between the continuum of 'amotivation' and 'intrinsic motivation', Deci and Ryan (1985) classified four 'extrinsically-regulated behaviors', varying in the extent to which the motivation is less or more self-determined (Ryan & Deci, 2000a; Ryan & Deci, 2000b). The first is *externally regulated motivation,* which occurs when a person acts to avoid other-controlled punishments or to obtain external rewards (Ryan & Deci, 2000b; Vansteenkiste & Ryan, 2013). In a STEM educational context, a pupil can, for instance, study well for STEM to avoid punishment from his parents or teacher. The second type of extrinsic motivation is entitled *introjected regulated motivation*. In this case an individual is motivated to engage in behavior to avoid feelings of guilt or anxiety or to be admired by others (Ryan & Deci, 2000b); for example, a student will try to obtain good grades for STEM to show that he is a 'good boy' (Vansteenkiste & Ryan, 2013). The third type of motivation is *regulation through identification*, which is more closely allied to being self-determined or autonomous because the individual personally embraces the value of an activity or norm, but does not necessarily find it interesting or enjoyable (Ryan & Deci, 2000b; Vansteenkiste & Ryan, 2013). The student, for instance, does not enjoy studying STEM, but is motivated to do his best because he wants to become a doctor, and realizes that STEM is important to achieving his goal. The last and most autonomous category of extrinsic motivation is *integrated regulation* and occurs when a person expresses a certain behavior because it matches his broader personal values and commitments (Ryan & Deci, 2000b; Vansteenkiste & Ryan, 2013). A student’s motivation is, for example, integrated regulated when she participates in STEM because she wants to develop renewable energy in her future career, as this fits into her pro-environment-friendly attitude. Figure 1 offers a visual representation of the motivation continuum.



AMOTIVATION	EXTRINSIC MOTIVATION				INTRINSIC MOTIVATION
	External Regulation	Introjection	Identification	Integration	
- Lack of perceived competence or lack of value	- External rewards or punishments - Compliance - Reactance	- Ego involvement - Focus on approval from self and others	- Personal importance - Conscious valuing of activity - Self-endorsement of goals	- Congruence - Synthesis and consistency of identifications	- Interest - Enjoyment - Inherent satisfaction

Figure 1. Based on the motivation continuum: Organismic Integration Theory Taxonomy of Regulatory Styles (Center for Self-Determination Theory, 2017).

Importantly, the literature based on SDT has shown that higher self-determined motivation has consistently been related to positive outcomes such as higher well-being, better performance, greater persistence, improved academic achievement and increased engagement (Vansteenkiste & Ryan, 2013; Tessier et al., 2010). Among these outcomes, engagement is a critical predictor of students’ academic learning, grades, achievement test scores, retention, graduation and academic resilience (Pajares & Graham, 1999; Reeve et al., 2004; Reeve, 2012; Skinner et al., 2008; Tessier et al., 2010).

Engagement is a multifaceted construct, consisting of behavioral, emotional and cognitive components (Fredericks, Blumenfeld & Paris, 2004). Reeve (2012) also suggests a fourth dimension: agentic engagement. In this study, we refer to engagement as the behavioral intensity (e.g. attention) and emotional quality (e.g. interest, enthusiasm) of a person’s active involvement during a task (Reeve et al., 2004). However, in other studies, engagement is also often conceptualized as on-task behavior, referring to overt student behaviors at home (e.g. effort and persistence with regard to schoolwork, participation and time on homework), or in the classroom (Lane & Harris, 2015; Raphael, Pressley, & Mohan, 2008; Ryan, 2000). Engagement can be measured at an individual level (e.g. Jang, Kim, & Reeve, 2012; Lee, Hayes, Seitz, DiStefano, & O'Connor, 2016) or at group level such as the classroom (e.g. Reeve et al., 2004; Sinatra, Heddy, & Lombardi, 2015). The latter is called collective engagement by Reeve et al. (2004). In the current study, we approach engagement as collective engagement.

1.3. Relationship between basic psychological need support, motivation and engagement

Tessier et al. (2010) have argued that motivation and engagement are both linked to basic psychological need support. In classes where teachers successfully improved their teaching style in terms of psychological need support, both students' self-determined motivation and engagement increased. In the study by Tessier et al. (2010), a pre-test post-test design was used, within a time period of three weeks. The teaching style was assessed, the students' engagement was observed, and the students psychological need satisfaction and motivation were measured by self-report. The successful improvement of the teachers' motivating style as measured in the post-test was assumed to be the originator of the positive student outcome. However, the authors did not explicitly test the link between the observed teaching style and the student outcomes.

Reeve et al. (2004) on the other hand, have explicitly investigated the link between teachers' observed teaching style and observed students' collective engagement. In their experimental study involving a delayed-treatment control group, they found that teachers displayed more autonomy-supportive behavior after training, which resulted in more engagement on the part of the students. Also, Skinner et al. (2008) investigated the link between teachers' motivating style and student engagement. They found that students who felt externally or internally pressured (low autonomy) at the beginning of the school year were increasingly feeling emotionally and behaviorally disengaged. On the other hand, students who felt highly autonomous and competent, and students who experienced secure relationships with teachers at the start of the school year, showed improvements in terms of engagement throughout the school year. However, in the studies by Reeve et al. (2004) and Skinner et al. (2008), although the link between basic psychological need support and collective engagement was tested in a direct manner, they did not connect these concepts with student motivation.

The relationship between motivation and engagement remains a subject of debate (Appleton, Christenson, & Furlong, 2008; Lee et al., 2016). Several authors consider engagement as an externalization of motivation, and thus as a motivational outcome (Stroet et al., 2013; R. Ryan, personal communication, February 6, 2017). Reeve et al. (2004) suggest that engagement contains intrinsically-motivated behavior and self-determined extrinsic motivation. Nevertheless, other authors consider motivation and engagement as two separate concepts, but not orthogonal. One could, for example, be motivated but not necessarily actively engaged in a task (Appleton et al., 2008; Connell & Wellborn, 1991). A few studies have investigated the possibility of a direct link between motivation and engagement in the context of physical education (Aelterman et al., 2012) and reading (De Naeghel et al., 2012). One study by De Naeghel et al. (2012) found that autonomous reading motivation related to qualitatively higher reading engagement. In other words, they found that students pay more attention and are more focused when they read for their own enjoyment, or when they believe that reading is personally relevant for them, than when they feel internally or externally pressured to read in their leisure time. A study in the context of physical education found that students who are more autonomously motivated are more engaged, whereas students who felt amotivated or externally pressured to participate in physical education activities show lower levels of engagement (Aelterman et al., 2012).

To the best of our knowledge, no studies have investigated a direct link between motivation and engagement in a STEM context. It is exactly this gap that we aim to address in the current study; we aim to directly link teachers' basic psychological need support with students' motivation and students' engagement. Consequently, we aim to combine the strengths of the studies by Tessier et al. (2010) and Reeve et al. (2004). Based on the literature investigating the direct link between motivation and engagement, we consider engagement as an externalization in terms of a behavioral and emotional expression of motivation. This implies that autonomous motivation contributes to higher levels of student engagement, while controlled motivation is negatively related to it.

In this study, we address the theoretical concepts of teachers' motivating style, students' motivation and students' engagement within the class context. The motivational atmosphere in a class is a result of social interactions between students and teachers and can vary across different classes (Aelterman et al., 2012). Hence, we approach motivation and engagement as collective class dynamics (Reeve et al., 2004). As shown in Figure 2, this paper hypothesizes that teachers' motivating style is directly linked to students' class motivation and students' collective engagement and, in addition, a predictive relationship between student motivation and engagement is assumed. More specifically, we hypothesize that controlled motivation (i.e. external regulation and introjected regulation) is negatively predictive for engagement, and that autonomous motivation (i.e. identified regulation and intrinsic motivation) is positively predictive for engagement.

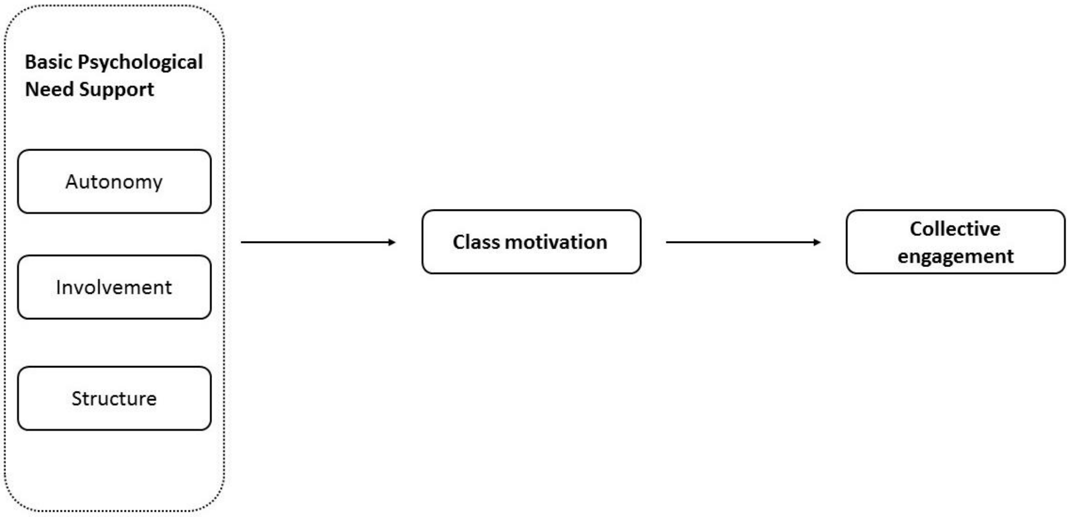


Figure 2. Link between basic psychological need support, class motivation and collective engagement.

Besides lacking an explicit link between the three key concepts of this paper, to the best of our knowledge, no previous research has yet investigated the link between teachers' motivating style and student motivation and engagement within the educational context of various STEM subjects. For instance, no such studies were reported in the review studies of Stroet et al. (2013) and Núñez and León (2015) about the effects of basic psychological need support in an educational context.

1.4. Aim and hypotheses

The purpose of the present study is to investigate:

(1) The relationship between STEM-teachers' motivating style and (1a) students' motivation towards STEM and (1b) students' engagement. We hypothesize that higher teachers' basic psychological need support predicts higher students' self-determined motivation, lower controlled motivation, and higher engagement.

(2) The relationship between students' motivation towards STEM and their engagement. We hypothesize that autonomous or self-determined motivation in

terms of studying a STEM subject is positively predictive, and that controlled motivation is negatively predictive for students’ engagement in the classroom.

2. Method

2.1. Participants and research setting

This study is embedded and conducted within the research project STEM@School (Knipprath et al., 2018). The project's aim is to develop and study the implementation of integrated STEM education in Flanders (northern region of Belgium). This resulted in an integrated STEM course in which students were challenged to solve authentic STEM problems. Integrated STEM education is an interdisciplinary educational approach which aims to remove the barriers between the four STEM disciplines (Wang, Moore, Roehrig, & Park, 2011). One of the overall aims of this approach is to increase students' achievement and motivation with regard to studying STEM in order to attract more students to professions that involve the use of STEM. To measure the effectivity of the integrated STEM approach in terms of these student outcomes, a pre-posttest design was used in this project. However, we also took into account other meaningful factors that may influence students' motivation with regard to studying STEM subjects. In this study, we focused on STEM-teachers' role, and more specifically STEM-teachers' motivating style.

A convenience sample of schools associated with the STEM@School project was used. To select a suitable number of participants in schools with varying characteristics, a stratified random sampling approach (based on the number of students and the provided fields of study) was used among the population of schools associated with the research project. This resulted in 17 schools, from each of which one 9th grade class was selected to participate in this study. All classes could be considered as STEM classes, however, in 12 of these classes students followed a study track in which STEM is more theoretically addressed (named 'Science and Mathematics'), and in the other 5 classes students followed a study track in which STEM is more practical-oriented (named 'Industrial Sciences'). In each of these classes, one mathematics lesson, one physics lesson, and - when included in the curriculum - one integrated STEM or engineering lesson, was observed. Hence, both traditional domain-specific STEM lessons and integrated STEM lessons were included in the observations.

After screening the visual and auditory quality of the observational data, 30 observations remained, resulting into 27 participating teachers (41% male, 59% female) and 359 9^{th} grade students (64% male, 36% female, age: *M = 14.55; SD =.85*). From these 27 teachers, four were physics teachers, seven mathematics teachers, three engineering teachers and 11 were teachers that taught the integrated STEM course. integrated STEM-teachers. One teacher taught mathematics, physics and (integrated) STEM and one teacher taught both mathematics and physics.

2.2 Procedure

30 classroom observations were conducted between January and May 2016. Each lesson was videotaped and had a duration of between 50 and 100 minutes. The teachers' motivating style was observed, as well as students' engagement. At the end of the school year during the post-test of the project, students' motivation was assessed using an online questionnaire. In line with Belgian legislation, teachers voluntarily participated in the observations, and permission was obtained from the students and their parents using a passive informed consent procedure.

2.3. Measures

Teachers' motivating style and students' engagement. To assess the teachers' motivating style and the students' collective engagement, we used an observation rating scale (Figure 3) developed by Reeve et al. (2004), including predetermined coding categories (Renninger & Bachrach, 2015)**.** This observation scale was developed after an extensive review of the SDT literature (Reeve et al., 2004). The scale consists of 18 items which assessed four measures: teachers' autonomy support (4 items), teachers' provision of structure (5 items), teachers' provision of involvement (4 items) and one measure of students' engagement, which included both behavioral and emotional engagement (5 items). Based on video recordings, each item was rated on a continuum ranging from 1 to 7. Sample items include, for example, controlling language versus informational language (autonomy support), teacher seems cold versus teacher seems warm (involvement), poor versus strong leadership (structure) and dispersed versus focused attention (students' engagement). Both the frequency and intensity of the teachers' and students' behavior were considered during the rating procedure. We used number 4 as anchor or starting point. Then, we gradually moved to the left when behavior from the left column was more present, and we moved to the right when behavior from the right column was more present. For instance, we started from 4 at the start of the lesson on the item 'Physical Proximity'. If the teacher kept staying up front during class, the score gradually decreased. But if we observed that the teacher regularly walked over to students, the score increased. If the teacher was most of the time involved with the students in close proximity, a 7 was allocated. A high single class-level score to each of the five items was given on students' engagement when engaged behavior or emotions were expressed by most or almost all students in the classroom.

Influence Attempts:
Behavior intended to produce a change in the flow of the class or the behavior of the other person.
Teacher-Initiated Hits (Influence attempts):
Student-Initiated Hits (Influence attempts):

Rater:
Teacher:
Classroom:
School:

Rating Period (circle one):
1st10m 2nd10m 3th10m 4th10m 5th10m
Number of Students:
Day/Date/Hour:

Teacher's **Autonomy Support**

Relies on Extrinsic Motivational Resources • Incentives, Consequences • Directives, Deadlines • Makes Assignments • Seeks Compliance	1 2 3 **4** 5 6 7	**Nurtures Intrinsic Motivational Resources** • Interest, Enjoyment • Challenge • Competence/Confidence • Choice-Making
Controlling Language • Controlling, Coercive • Should, Must, Have to, Got to • Pressuring, Rigid, No nonsense	1 2 3 **4** 5 6 7	**Informational Language** • Informational • Flexible • Not at All Controlling
Neglects Value, Importance of Task/Lesson/Behavior • Neglects Value, Meaning, Use, Benefit, Importance	1 2 3 **4** 5 6 7	**Identifies Value, Importance of Task/Lesson/Behavior** • Identifies Value, Meaning, Use, Benefit, Importance • This is important because...
Reaction to Negative Affect: Is Not OK: Change it • Neg. Affect is Unacceptable • Tries to Fix, Counter, or Change • into Something Else	1 2 3 **4** 5 6 7	**Is OK: Listens, Accepts** • Listens Carefully • Open to Complaints • Accepts as OK, Valid Reaction

Teacher's **Structure**

During Introductions/Directions:		
Absent, Confusing Unclear, Complicated • Rules, Procedures are Confusing, Absent • Little or no organization	1 2 3 **4** 5 6 7	**Clear, Predictable Understandable, Detailed** • Clearly Stated Procedures • Frames Upcoming Lesson Well • Clear Organization
During Lessons/ While students learn		
Poor Leadership • Fails to Show Leadership • No Plan, No Goals	1 2 3 **4** 5 6 7	**Strong Leadership** • Organized, Leader, Conductor • Clear Plan, Clear Goals
Low, Easy Workload • Little Challenge, Slow Pace • Asks for only Small Capacity	1 2 3 **4** 5 6 7	**High, Hard Workload** • Much Challenge, Fast Pace • Asks for Full Capacity
Scaffolding is Fully Absent • Lack of Hints, Clues, Tips • Questions Missed, Answered Poorly	1 2 3 **4** 5 6 7	**Scaffolding is Richly Present** • Hints, Clues, Tips, Reminders • Answers Questions Well, Fully
During Feedback, Post-Performance Commentary		
None, Ambiguous, Off-Task, Rambling	1 2 3 **4** 5 6 7	**Skill-Building, Informative, Instructive**

Teacher's **Involvement**

Seems Cold, Closed • Business-like • Doesn't Enjoy Time with Ss	1 2 3 **4** 5 6 7	**Seems Warm, Open** • Expresses Affection, Caring • Does Enjoy Time with Ss
Withholds Personal Resources • Time, Attention, Energy	1 2 3 **4** 5 6 7	**Invests Personal Resources** • Time, Attention, Energy
Physical Proximity: Distant • Keeps Distance • Stays Up Front During Class	1 2 3 **4** 5 6 7	**Physical Proximity: Close** • Walks over to Students • Stands Near/Sits Close
Knows Students: No Not at All • No Mention of Names, Academic/Personal Histories	1 2 3 **4** 5 6 7	**Knows Students: Yes, Detailed Knowledge** • Knows Names, Academic/Personal Histories

Students Collective **Engagement**

Dispersed Attention	1 2 3 **4** 5 6 7	**Focused Attention**
Passive, Slow, Minimal Effort	1 2 3 **4** 5 6 7	**Active, Quick, Intense Effort**
Verbally Silent • Students Don't Talk, Ask Questions, Discuss	1 2 3 **4** 5 6 7	**Verbally Participating** • Students Do Talk, Ask Questions, Discuss
During Challenge, Failure or Confusion		
Gives Up Easily • Decreases Effort over Time	1 2 3 **4** 5 6 7	**Persists** • Increases Effort over Time
Flat Emositive Tone • Bored, Disinterested, Flat	1 2 3 **4** 5 6 7	**Positive Emotional Tone** • Enjoyment, Interested, Fun

Note for Each Rating: Use the bold, underlined **4** as your anchor/starting point.

Figure 3. Observer's rating sheet to score teachers' autonomy support and students' engagement (Reeve et al., 2004).

Two researchers rated the items independently to avoid social influence bias. The interrater reliability, based on the correlation coefficients, was satisfactory (*IRR* = .87). For the first five observations, the raters explicitly discussed each score they gave. Hence, we guaranteed that the scales were interpreted in the same way by both researchers. In the event of a different interpretation of the observation measure, the scores were modified after discussion. For the remaining observations, scores were not justified when a conflict in scores occurred. After this observation process, the two independent scores of the raters were converted to an average score per item for conducting the analyses.

The reliability of the subscales was examined by calculating Cronbach's alpha, as shown in Table 1. Teachers' autonomy support, teachers' involvement and students' engagement all showed Cronbach's alpha > .80, and teachers' structure initially showed Cronbach's alpha = .71. As the reliability improved as a result of deleting the first item (Cronbach's alpha = .78), the item 'structure during introduction' was removed, resulting in a scale of 4 items instead of 5. This means that a teacher might clearly frame the upcoming lesson during the introduction, which might be relatively easy to ensure. Still, this does not have to imply that a teacher also shows strong leadership skills and provides structure throughout the lesson.

Table 1
Reliability of the subscales of the rating scale for teachers' motivating style and students' engagement

	Autonomy support	Structure	Involvement	Engagement
Cronbach's alpha	.80	.78	.82	.92

Students' motivation. As motivation with regard to STEM-related subjects is difficult to observe as a general class group characteristic, we used individual self-report questionnaires. Two controlled types of motivation (external regulation and introjected regulation) and two autonomous types of motivation (identified regulation and intrinsic motivation) were assessed at the end of the school year. The timing of this assessment was based on choices in the project. Students' individual scores on controlled motivation and autonomous motivation were averaged to create a class score. The questionnaire was based on the Self-Regulation Questionnaire (SRQ; Ryan & Connell, 1989) and consists of 15 items which assess the motivation for learning physics, engineering, mathematics and integrated STEM. The participants indicated for each separate subject how important a motivational reason was for their own study behavior on a five-point Likert scale, ranging from 1 = *strongly disagree* to 5 = *strongly agree.* The number of items, an example item and the reliability of each subscale can be found in Table 2. The validity of the SRQ has been demonstrated by studies in various domains (e.g. Levesque et al., 2007). All subscales in the current study showed sufficient psychometric properties, as Cronbach's alpha > .80 was achieved.

Table 2
Number of items, example item and reliability of the subscales of students' motivation

	Controlled motivation		Autonomous motivation	
	External regulation	Introjected regulation	Identified regulation	Intrinsic motivation
N items	4	4	4	3
Example item	I try to do well in mathematics because that's what I am supposed to do	I am studying engineering because I would feel ashamed if I didn't	I am trying to do well in physics because I personally value this subject	I usually study mathematics because I find it interesting
Cronbach's alpha	.83	.85	.87	.85

2.4. Plan of Analysis

To test the hypothesis concerning the effect of STEM-teachers' motivating style on students' engagement, a statistical regression model was created, in which class group characteristics were linked with student outcomes. Considering that students learn together in class groups, we could expect that students' motivation and the engagement between students in the same class group will be more highly correlated than students' motivation and engagement between students in different class groups. Multilevel modelling allows data to be clustered in groups (in this case, class groups) and is therefore suitable for this research context. This study used a two-level model where students at level 1 were nested within class groups at level 2. Multilevel analyses were computed using JMP (John's Macintosh Project) version JMP pro 13. Similarly, multilevel analysis was performed to discover the relationship between teachers' motivating style and students' motivation. Next, multilevel analysis was performed to evaluate whether or not students' controlled or autonomous motivation can predict students' engagement.

3. Results

In Table 3, the means, standard deviations and correlations between teachers' motivating style, students' motivation and students' engagement are shown. The concepts autonomy support, structure and involvement are mutually strongly correlated (correlations varied from .72 to .84) and furthermore consecutively correlated with engagement (correlations varied from .82 to .83). The average Variance Inflation Factor (VIF) for autonomy support, structure and involvement was 2.64, indicating no problems with collinearity between the three variables of basic psychological need support.

Table 3
Means, standard deviations and correlations between teachers' motivating style, students' motivation, and engagement

	Teachers' motivating style			Students' motivation		Students' engagement
	1. Autonomy support	2. Involvement	3. Structure	4. Controlled motivation	5. Autonomous motivation	6. Engagement
1.						
2.	.84***					
3.	.72***	.73***				
4.	-.38*	-.33	-.14			
5.	-.01	.12	.32	-.10		
6.	.83***	.82***	.82***	-.39*	.25	
M	4.65	5.21	5.11	2.64	3.14	4.66
SD	1.10	.95	.94	.32	.41	1.25

Note. *p< .05. **p<.01. ***p<.001.

3.1. Relation between STEM-teachers' motivating style and students' motivation

Multilevel analysis with class group as a random factor was performed for the prediction of students' motivation for learning STEM subjects due to the teachers' motivating style. Results can be found in Table 4. The model with teachers' autonomy support, involvement and structure and class group as random effects did not consistently predict students' motivation, as linear regression showed that only structure could positively predict autonomous motivation (β = .26, p<.05), while autonomy support negatively predicted autonomous motivation (β = -.22, p<.05). No significant results for controlled motivation were found. Note that teachers' involvement was never predictive for students' motivation. Approximately 80% of the variation in students' controlled motivation is a function of the class group to which they belong (ICC = 0.80), while 76% of the variation in students' autonomous motivation is a function of the class group (ICC = 0.76). These correlations indicate strong average within-group agreement for the motivation measures.

Table 4
Relationship between teachers' motivating style and students' motivation

	β Autonomy support	β Structure	β Involvement
Controlled motivation	-.08	.07	-.01
Autonomous motivation	-.22*	.26**	.10

Note. *p<.05. **p<.01. ***p<.001.

3.2. Relation between STEM-teachers' motivating style and students' engagement

The relation between STEM-teachers' motivating style and students' engagement with class group as the random effect is reported in Table 5. Higher levels of teachers' autonomy support were marginally predictive (β = .40, p=.06) and structure was significantly predictive (β = .55, p<.05) for students' engagement. With regard to involvement, no significant relationship between students' engagement was found. Hence, a positive relationship between STEM-teachers' motivation style and students' engagement was found: the more the teachers provided autonomy support and structure, the more students displayed engaged behavior. 24% of the variation in engagement is a function of the class group to which they belong (ICC = 0.24).

Table 5
Relationship between teachers' motivating style and students' engagement

	β Autonomy support	β Structure	β Involvement
Engagement	.40	.55*	.27

Note. *p<.05. **p<.01. ***p<.001.

3.3. Relation between motivation and engagement

Multilevel analysis with class group as a random factor was performed for the prediction of students' engagement with motivation for learning STEM subjects. These regressions indicated that controlled motivation (extrinsic regulation and introjected regulation) could negatively predict engagement in a marginally significant way (β = -1.43, p=.06). Engagement could not be predicted by autonomous motivation (identified regulation and intrinsic motivation) in this study. The strengths of the relationship between motivation and engagement can be found in Table 6, where the standardized coefficients are reported. Multilevel analysis revealed that approximately 3% of the variation in students' engagement is a function of the class group to which they belong (ICC = 0.03).

Table 6
Relationship between students' motivation and engagement

	β Controlled motivation	β Autonomous motivation
Engagement	-1.43	.65

Note. *p<.05. **p<.01. ***p<.001.

4. Discussion

Using SDT as a theoretical approach, the aim of this study was to gain more insight into the impact of teachers' motivating style on students' motivation and engagement, particularly in a STEM educational context. Furthermore, we aimed to build further on the existing literature with regard to motivation and engagement, by exploring the relationship between these two concepts. In Figure 4, a summary of the results is displayed graphically.

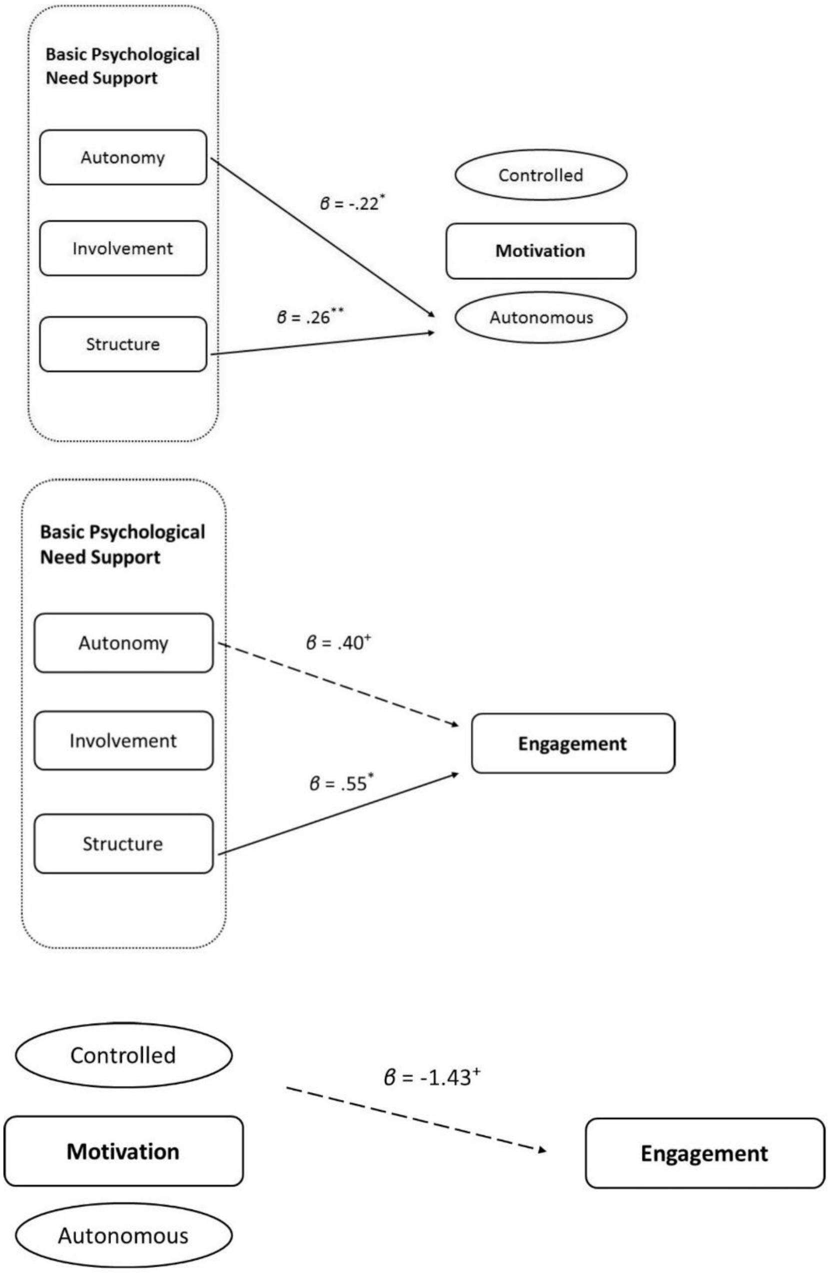


Figure 4. Summary of results: link between basic psychological need support, students' motivation and engagement.

The design of this study was unique, as in previous research no explicit link between the three key concepts examined in this paper was made within the educational context of various STEM-subjects (Stroet et al., 2013; Núñez & León, 2015). Other studies exclusively focused on one particular STEM-subject within the perspective of SDT, e.g. mathematics (Valås & Søvik, 1994), organic chemistry (Black & Deci, 2000), physics (Zhang, Bobis, Wu, & Cui, 2018), and biology (Hofferber, Basten, Großmann, & Wilde, 2016).

4.1. STEM-teachers' motivating style and students' motivation

Conforming to the SDT and other empirical studies (e.g., Black & Deci, 2000; Valås & Søvik, 1994), we hypothesized that greater teachers' basic psychological need support (provision of autonomy, relatedness and structure) in STEM lessons predicts higher autonomous class motivation and lower controlled class motivation in terms of studying STEM (hypothesis 1a).

The results in this study show that *teachers' provision of structure* is positively linked with autonomous motivation (i.e. identified regulation and intrinsic motivation), which is in line with our hypothesis. Feelings of competence have been considered central to motivation in achievement settings (Nicholls, 1989), which is also reflected in the results of the current study. No relationship was found between teachers' provision of structure and controlled motivation.

Furthermore, *teachers' involvement* was not predictive for either students' autonomous or controlled motivation. In the literature, less attention has been given to the role of relatedness in educational settings (Cox & Williams, 2008; Lavigne et al., 2007; Curran, Hill, & Niemiec, 2013). One could hypothesize that it is less likely to find a relationship between feelings of relatedness and motivation.

Regarding teachers' autonomy support, no predictive relationship was found for students' controlled motivation. Surprisingly, *teachers' autonomy support* was negatively associated with autonomous motivation, given that we expected a positive relationship to emerge. A possible explanation for this unexpected result could be that we did not include intermediate variables such as students' self-reported basic psychological need satisfaction. Lavigne et al. (2007) for example, did find that science teachers' autonomy support positively influences students' self-perceptions of autonomy. In turn, the latter has a positive impact on students' autonomous motivation in science. Another explanation could be associated with a time-related factor. The self-report of students' motivation took place a few months after the class observations, and therefore certain personal or school-related events could have affected students' motivation towards STEM. For instance, teachers' motivating styles towards the end of the school year could differ due to time pressure before the exam period, which might subsequently influence students' motivation. Learning materials could also influence students' motivation. For instance, Hofferber et al. (2016) found that autonomy-supportive teaching behavior led to more intrinsic motivation, but these positive effects seemed to be dependent on the interestingness of the teaching materials.

4.2. STEM-teachers' motivating style and students' engagement

In line with our hypothesis (1b), this study confirms that STEM-teachers' motivating style positively affects students' collective engagement. For two of the three basic psychological needs (autonomy support and structure), a positive association was found with students' engagement. The finding that basic psychological need support is predictive of students' engagement is in line with the study by Skinner et al. (2008) who investigated the link between teachers' basic psychological needs support and students' self-reported engagement. Skinner et al. (2008) made use of self-report measures for teachers and students, and argued that teacher support, through its effects on students' perceptions of their teacher's motivating style, influences their engagement. The results in the current study also confirm the findings of Reeve et al. (2004), who made use of observational data, and found a clear effect of teachers' motivating style on students' collective engagement. In conclusion, the findings of this study - in combination with the evidence of studies using different methodological approaches - demonstrate the relevance of teachers' motivating style when it comes to students' engagement.

4.3. Student motivation and engagement

The hypothesis that higher mean levels of autonomous motivation are positively predictive, and higher mean levels of controlled motivation negatively predictive for students' collective engagement in the classroom (hypothesis 2) has partially been confirmed. In this study, only controlled motivation was negatively linked to students' engagement. This means that low levels of engagement can be considered as an externalization of controlled motivation. Other studies found mixed evidence with regard to the relationship between motivation and engagement. De Naeghel et al. (2012) discovered a positive link between autonomous motivation and reading engagement, but did not find a negative link with controlled motivation. The study by Aelterman et al. (2012) did find a positive link between autonomous motivation and engagement in physical education, and a negative link between controlled motivation and engagement. The mixed evidence of these previous studies indicates that the link between motivation and engagement could be dependent on the context. A possible explanation for the results of the current study could be that the design of the study (i.e. different measurements and different time frames; see limitations) was not sufficient to reveal a positive relationship between engagement and autonomous motivation. If these measurements were all self-reported, finding a direct link could have been more likely. At the same time, we argue that the use of different measurement instruments in this study to capture students' engagement (observational data) and students' motivation (student selfreports), are a strength as a multi-method approach can have a positive impact. A combination of measures has an advantage over the use of a single instrument; self-reported measures have the problem of retrospection, and observations have the possibility of observer bias such as seeing what one is expecting (Greene, 2015; Sinatra et al., 2015).

4.4. Implications for STEM educational practice

Based on the findings regarding hypotheses 1a and 1b, we can conclude that taking into account teachers' motivating style is highly relevant for STEM education research and practice, in order to motivate and engage students within the class context. We found a clear link between teachers' provision of structure and students' autonomous motivation and engagement. Although the relationship between autonomy support and autonomous motivation was less clear in this study than in some others, we found a clear link with engagement. Hence, we suggest that efforts to increase STEM-teachers' basic psychological need support are important to enhance the motivational atmosphere in various STEM classes. Moreover, a previous empirical study (Lavigne et al., 2007) found that the teacher motivating style in general can lead to more students pursuing a STEM-career.

Importantly, some STEM learning environments could be perceived as being better suited to nurturing one of the three basic psychological needs. A teacher-centered learning environment such as a lecture could be suited to allowing teachers to provide structure, but might be less evident when it comes to supporting a class group's need for autonomy and relatedness. In contrast, a student-centered learning environment might provide more room for supporting the class group's need for autonomy and relatedness (Baeten, Dochy, & Struyven, 2013). This has important implications, taking into consideration the fact that plenty of literature and educational practitioners advocate a shift in teaching and learning STEM towards student-centeredness (Sawada et al., 2002). The current international focus on integrated STEM education (iSTEM education), also requires a student-centered learning environment (Nadelson & Seifert, 2017). As stated, such environments might provide more room to support students' need for autonomy and relatedness (e.g. through problem-centered learning and cooperative learning), but at the same time these student-centered learning environments entail the risk that teachers provide insufficient structure to students (Struyf, De Loof, Boeve-de Pauw, Van Petegem, 2019). As we found that both autonomy and competence support are crucial in order to supporting students' classroom engagement, we emphasize in line with Kirschner, Sweller and Clark (2006), the necessity of teacher's guidance throughout students' learning process, especially in student-centered learning environments. An illustration of this issue was provided by Eckes, Groβmann and Wilde

(2018). They argued that students' feelings of competence were usually frustrated in extracurricular settings such as museums, but found that extra provision of structure in these settings was effective in terms of fostering this basic psychological need. Consequently, professional development programs that aim to improve STEM teachers' motivating style within student-centered learning environments, can especially focus on how teachers can sufficiently provide both autonomy and structure.

Also, professional development programs could incorporate information and guidance for teachers on how to use a need-supportive motivating style during instruction in all possible STEM learning environments, in order to increase students' engagement in STEM. Additionally, it should be noted that providing structure in the classroom is one possible way in which teachers can support students' feelings of competence. Other approaches could also enhance competence support, such as giving personalized feedback. Furthermore, attention should be paid to STEM teachers' own feelings of competence with regard to teaching STEM, as previous research shows that the more teachers feel competent, the more their teaching is autonomy-supportive (Bennett, Ng-Knight, & Hayes, 2016).

4.5. Limitations and directions for future research

The current study adds to the SDT-literature in the STEM-context, and links the concepts of psychological need support, engagement and motivation in one study using multiple measures. However, it has some limitations which future researchers can attempt to eliminate in order to enhance our understanding of the subject.

A first important limitation is that observations were conducted during one particular period of time during the school year, and were linked to students' motivation towards STEM-related subjects at the end of the school year. Hence, this paper involves a cross-sectional study which means that no causal inferences can be made about the influence of basic psychological need support on engagement and motivation. Further research could add causal inferences to the relationships that were discovered in the current study. Therefore, we suggest a cross-lagged longitudinal study which measures teaching style, engagement and motivation at multiple points in time.

Furthermore, observational research has some limitations. It is possible that teachers' observed motivating style and students' engagement is not representative of the teachers' and students' usual behavior. Nevertheless, an observation involving a video camera can always have an effect as the camera effect does not necessarily disappear after more than one observation. Future research that uses observational data to capture students' engagement ideally needs to conduct a number of observations during the school year. Also, future research could measure teachers' motivating styles based on students' perceptions, to eliminate the possibility that a teacher's motivating style is perceived differently by students than by the researchers. However, the combination of observational data with self-reported measurements in the current study also has advantages, such as that no retrospection bias is likely to occur for the variables that are observed.

An interesting path for future research, is the investigation of a possible differential impact of the subject. The current study included only thirty class observations (divided over mathematics lessons, physics lessons, integrated STEM lessons and engineering lessons), and did not allow to make conclusions with regard to this matter.

A final remark is that engagement was measured at a meso-level (collective engagement from the class group), while motivation was measured at a micro-level (individual student) and scores were averaged to create a class score (group level). Future research, investigating the link between motivation and engagement on an individual level, can use students' self-reported motivation as well as self-reported engagement in order to create a more comprehensive and fine-grained view of the link between engagement and motivation.

5. Conclusion

This study showed the importance of teachers' motivating style in a STEM educational context. In particular, teachers' provision of structure is significant in terms of increasing students' motivation to study STEM-related courses on the one hand, and students' engagement in STEM classes on the other. In addition, teachers' autonomy specifically was significantly predictive of students' engagement. Regarding the link between motivation and engagement, a negative relationship was found between controlled motivation and engagement. The direct investigation of the connection between the concepts of teachers' motivating style, students' motivation and students' engagement in one study is novel. Also, the application of SDT-concepts in the broad STEM-context is innovative, and adds to the STEM-literature.

Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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